AGENDA FOR THE
ENGLEWOOD CITY COUNCIL
STUDY SESSION
MONDAY, OCTOBER 10, 2011
COMMUNITY ROOM
6:00 P.M.

I. **UV/CH2M Hill Report**
Utilities Director Stu Fonda and representatives from CH2M Hill will discuss their report on ultraviolet disinfectant at the Wastewater Treatment Plant.

II. **City Manager's Choice**

III. **City Attorney's Choice**

IV. **Council Member's Choice**

Please Note: If you have a disability and need auxiliary aids or services, please notify the City of Englewood, 303-762-2407, at least 48 hours in advance of when services are needed. Thank you.

Littleton/Englewood WWTP Assessment of Existing Disinfection System

Littleton City Council Meeting
June 21, 2011

CH2MHILL

Background – Previous Work by Others

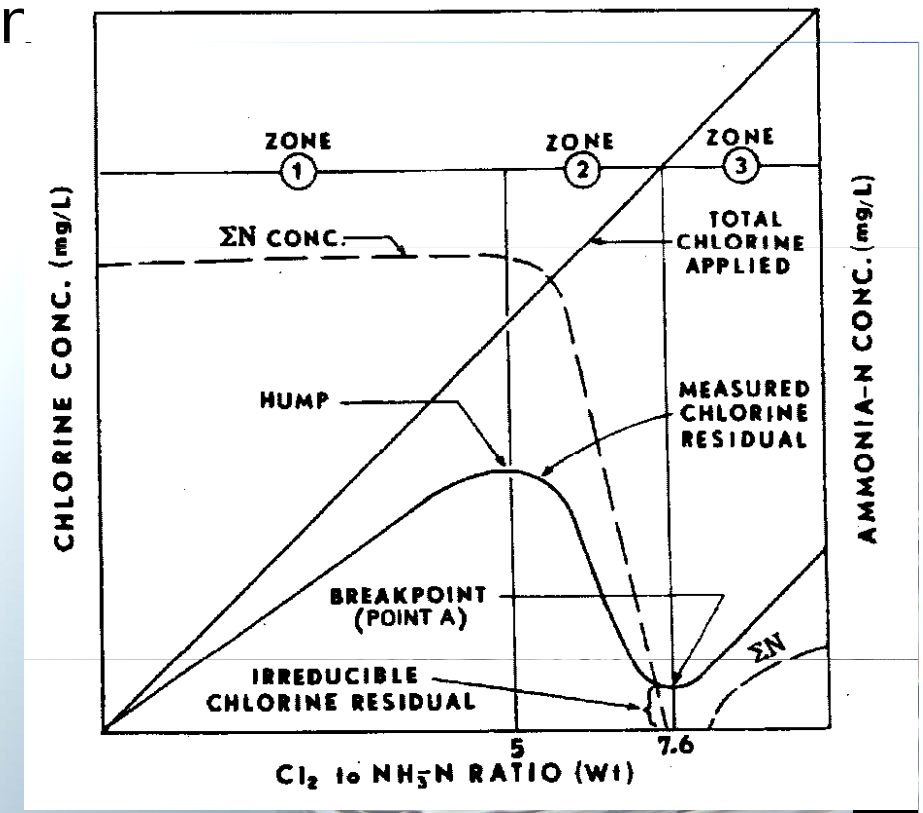
- B&C previously evaluated the existing system and alternative disinfection methods to comply with future ammonia limits.
- Previous finding for the existing disinfection approach:
  - "cannot be expected to consistently meet permit limitations" based on newly adopted discharge limits for the WWTP
- Identified UV disinfection as the selected alternative
- Ammonia Compliance Schedule approved by CDPHE and included in WWTP's discharge permit

Background – Previous Work by Others

- Previous work recommended UV disinfection based on following concerns with chlorine disinfection options:
  - Low ammonia concentrations complicate chlorination chemistry
  - Difficult process control
  - On-line ammonia analyzers, which are necessary for the chlorine disinfection options, are difficult to calibrate and do not always produce accurate results
  - Options with ammonia *addition* may increase risk of future permit violation
- The intent of CH2M HILL's study is to re-evaluate the feasibility of the chlorine disinfection options

Why Is Ammonia Important for Disinfection at the L/E WWTP?

- Ammonia is present in wastewater
- Ammonia must be removed to meet discharge limits
- Ammonia must be present at sufficient concentrations for effective chlorine disinfection
- Competing objectives result in a balancing act to remove enough but not all ammonia
- Chlorine/ammonia chemistry is complicated: the correct chemical ratio is required for effective disinfection

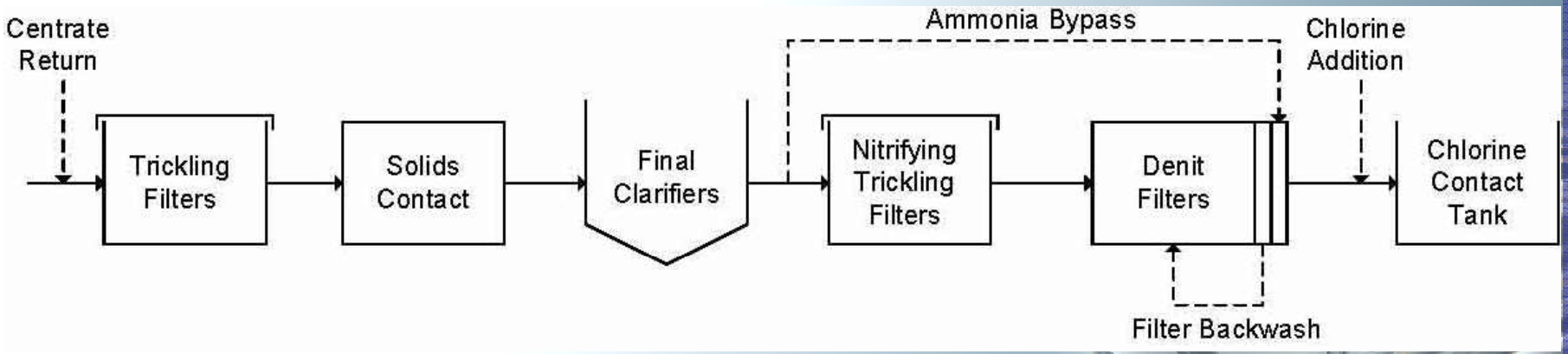


Evaluation of Chlorine Disinfection Options Previously Considered

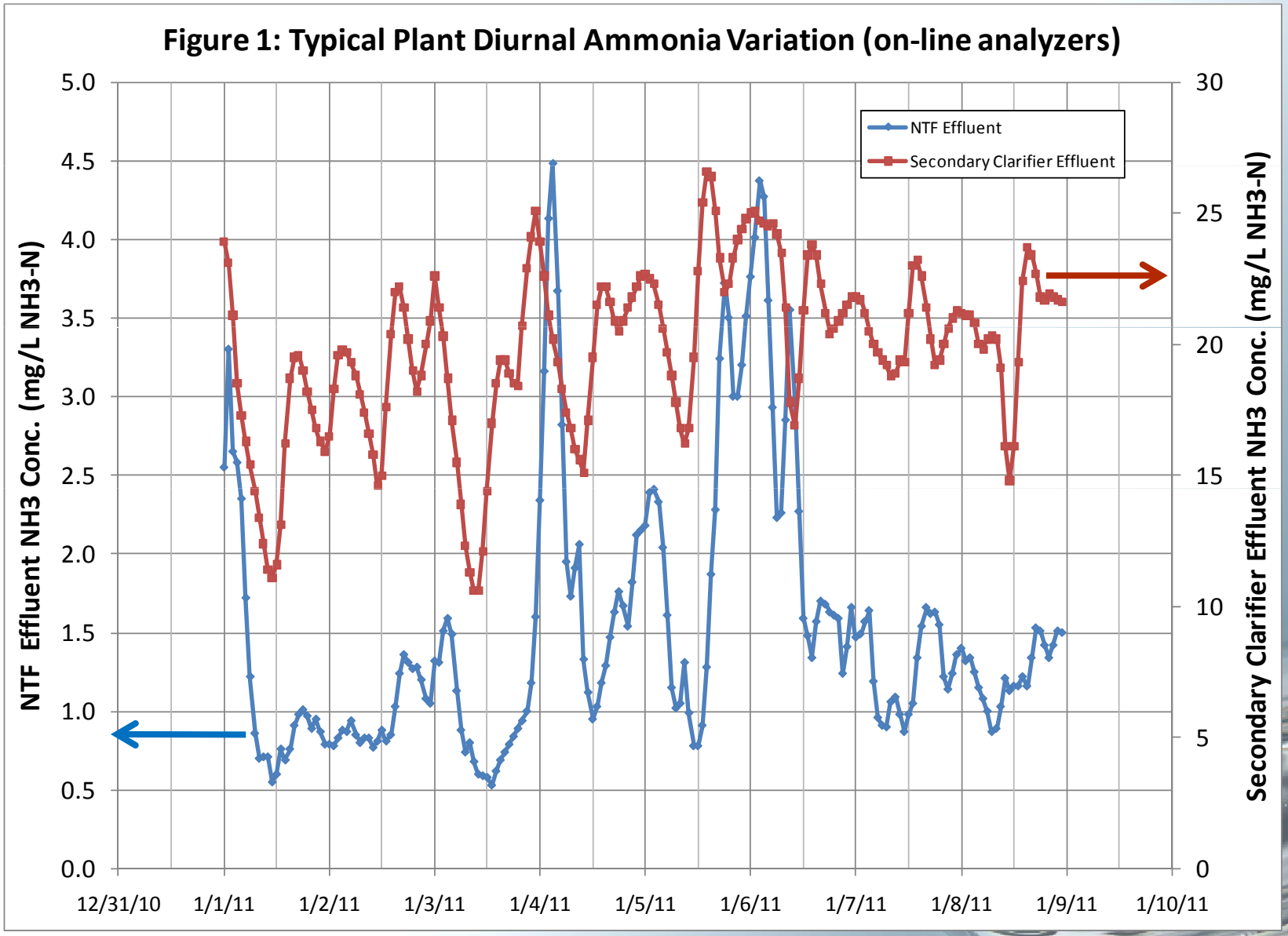
- **Option #1:** Free chlorine disinfection by breakpoint chlorination – high chlorine dose, high cost, not controllable, not recommended
- **Option #2:** Monochloramine disinfection using existing NTF Bypass
- **Option #3:** Monochloramine disinfection using external ammonia addition – higher cost than Option 2, no additional advantages

Difficulties with Current Approach

- Current approach bypasses some ammonia around nitrification
- Other plant operations complicate the process
  - Typical diurnal ammonia variations
  - On-line ammonia analyzer accuracy and reliability
  - Denit filter bumping and backwashing
  - NTF bypass control algorithm
  - Centrate return pumping

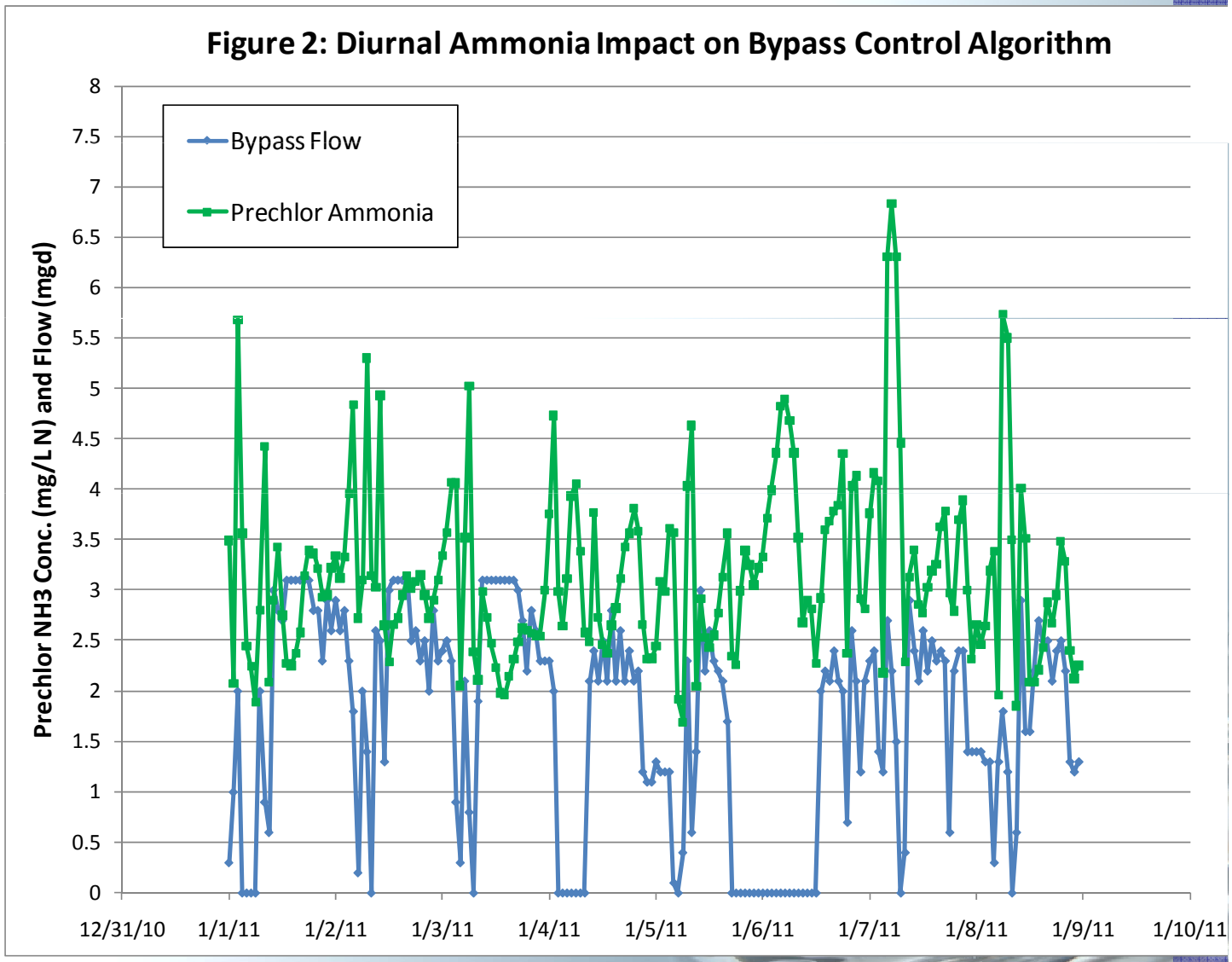


Ammonia Varies Significantly through the WWTP



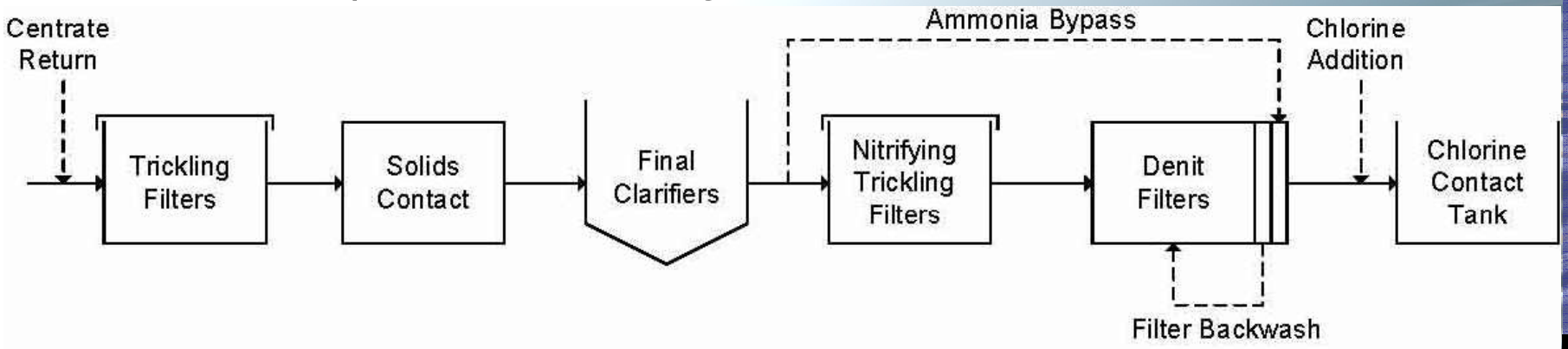
Ammonia Variations through the Plant Can Significantly Impact Control of the Disinfection Process

- Control at 2 mg/L not effective
- Prechlor ammonia varies from 1.5 to 5 mg/l
- Bypass flow varies between 0-3 mgd



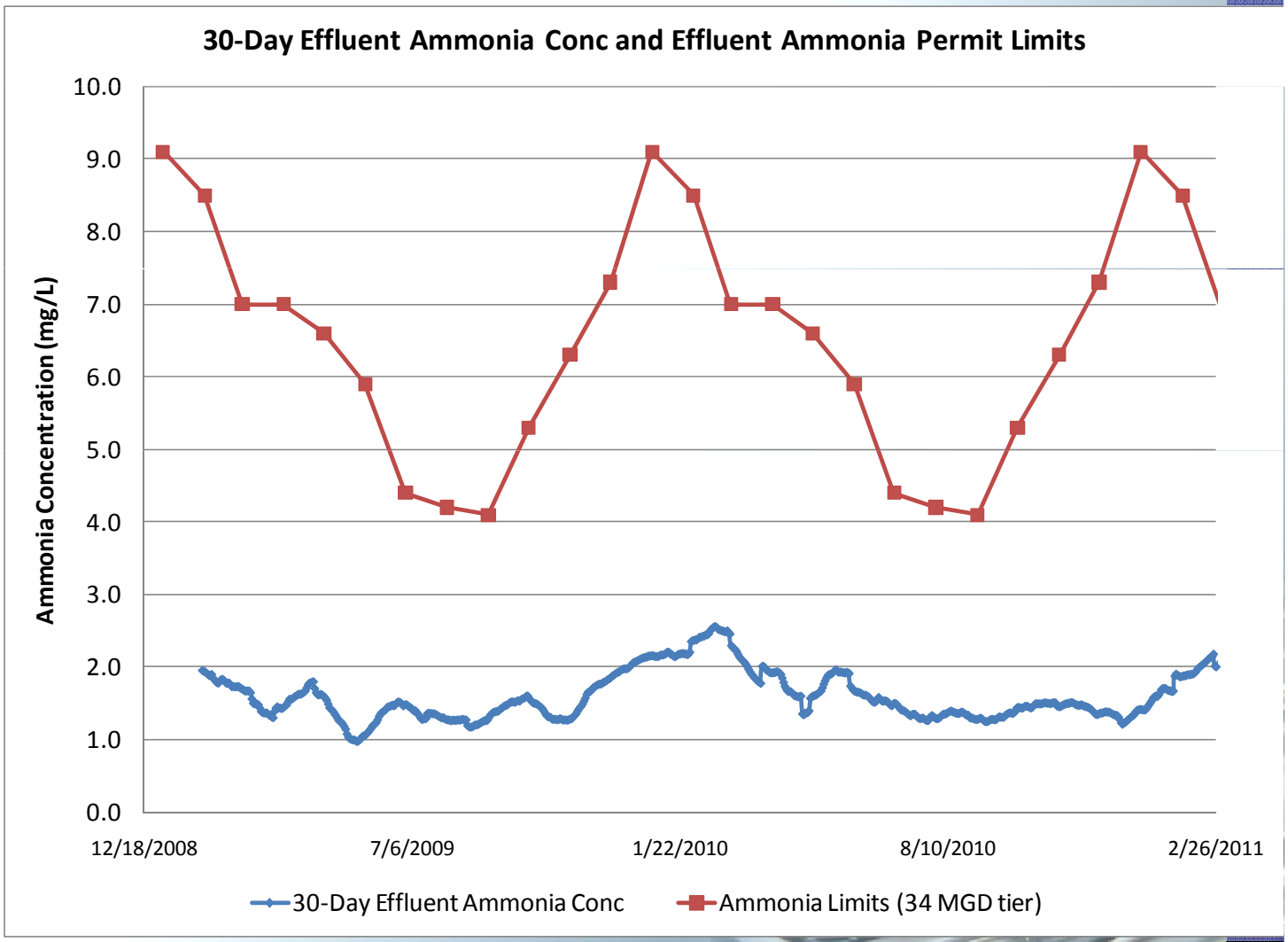
Difficulties with Current Approach

- Typical diurnal ammonia variations
- Denit filter bumping and backwashing
  - Large sudden flow variations
  - Rapid change in ammonia concentration
- Centrate pumping:
  - Sudden increase in ammonia concentration in NTF bypass
- NTF bypass control algorithm
  - Over-reacts to ammonia changes
  - Doesn't predict flow changes from backwash events



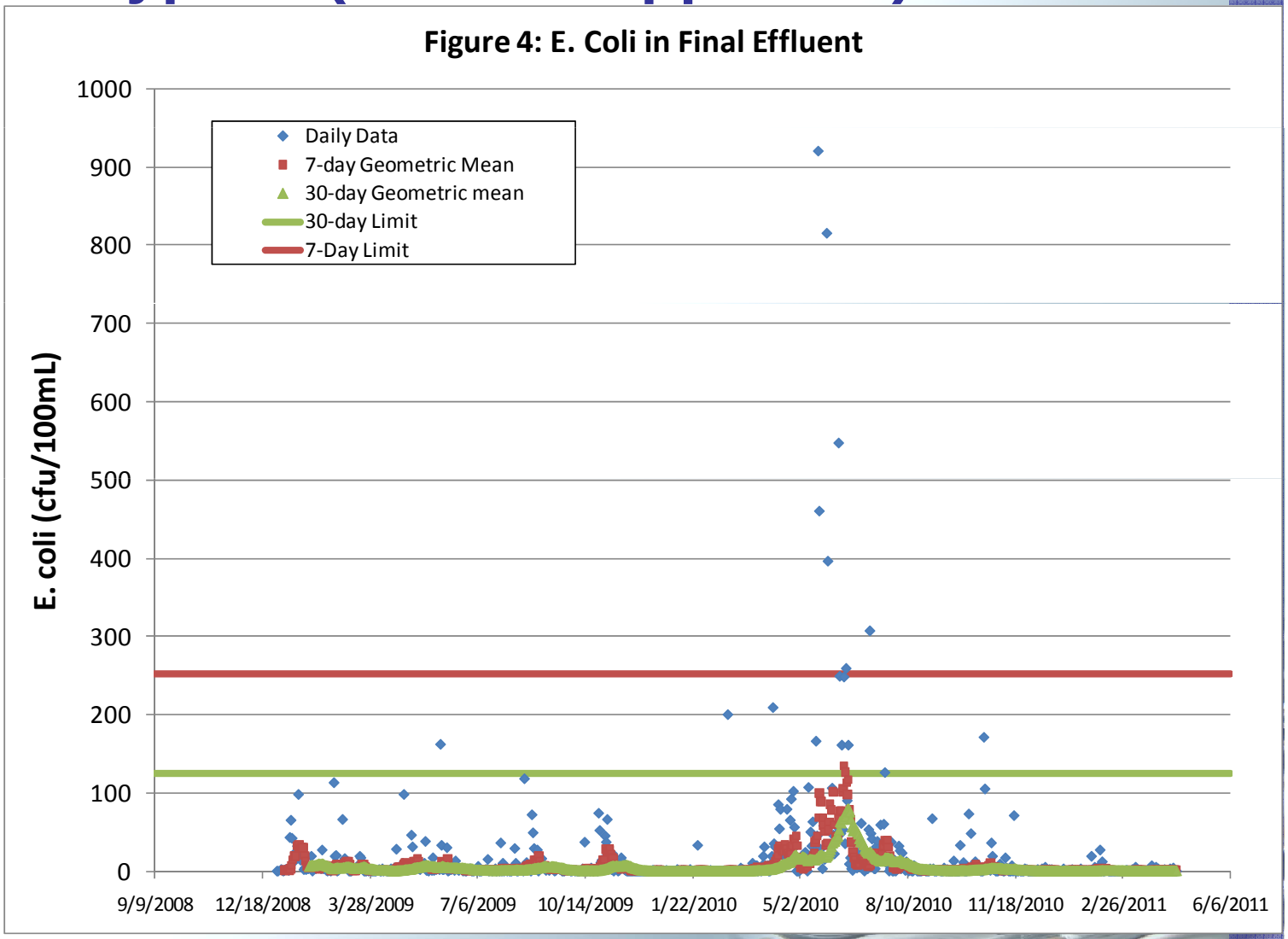
Ammonia Compliance with Future Regulations Using NTF Bypass (Current Approach)

- The most restrictive future ammonia limit is 3.2 mg/L (50 mgd, September)
- Compliance with future ammonia requirements has occurred
- Periodic inhibition events are problematic, but are more disruptive to ammonia compliance than disinfection



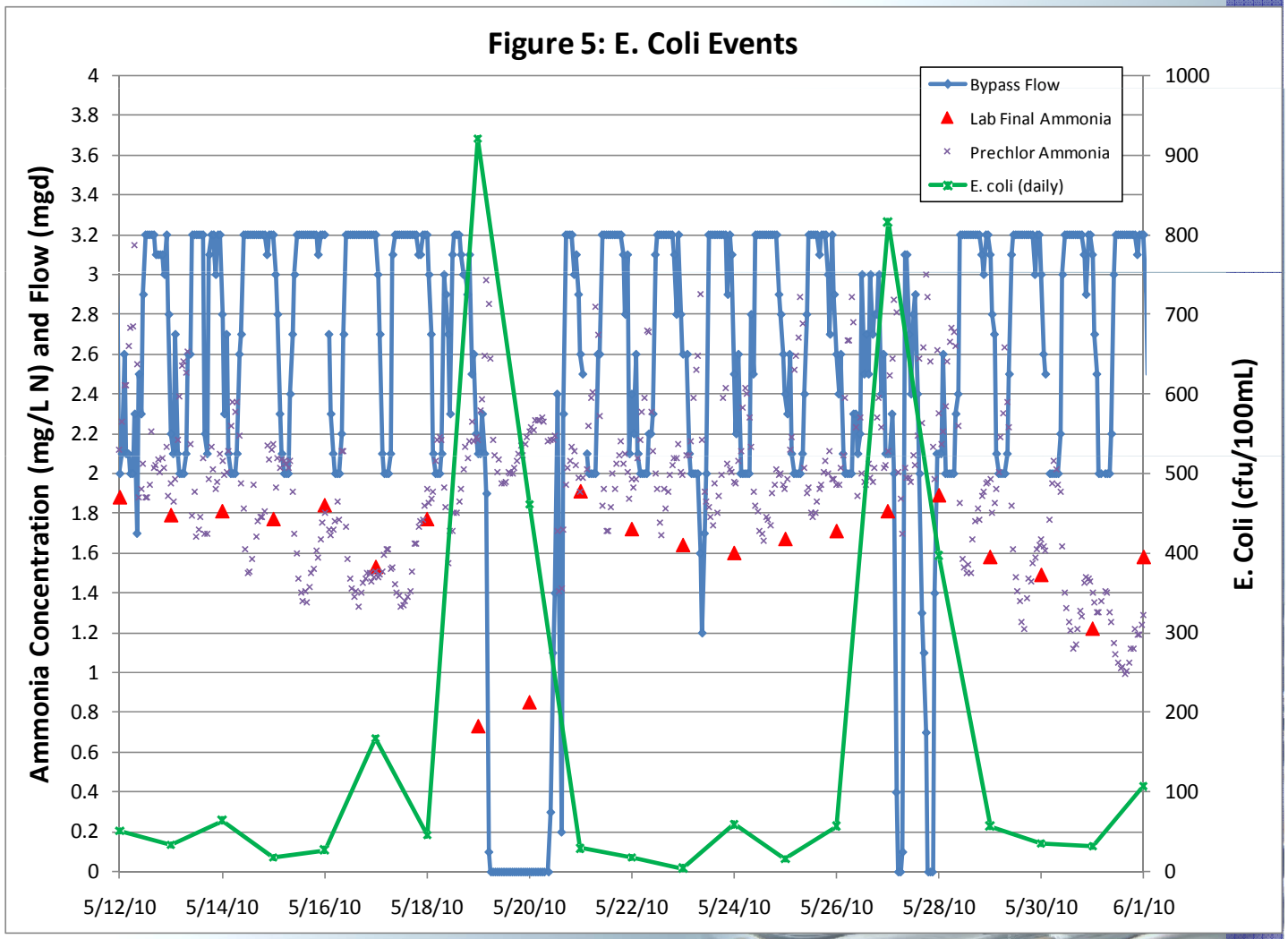
E. Coli Compliance with Future Regulations Using NTF Bypass (Current Approach)

- *E. Coli* limit will be more difficult to meet than fecal coliform
- Performance is generally good
- Almost exceeded future limits in summer of 2010



What Caused Elevated *E. coli* Levels in Summer 2010?

- Two *E. coli* "events" caused by erroneous on-line ammonia analyzer; (0.8 mg/L by lab versus 3 mg/L by on-line analyzers)
- Consequently, ammonia to the CCT was much lower than intended; resulted in formation of less germicidal chlorine species



Summary of Current Approach

- Objectives:
  - 1. Compliance with ammonia limit
  - 2. Disinfection (bacterial indicator organism compliance)
  - 3. Dechlorination
- Operators have done an excellent job achieving compliance with complicated system and numerous variables
- Potential improvements to current approach:
  - Control improvements
  - Dampening of bypass flow, replace pump for minimum flow
  - Off-line denit filter backwash supply
  - Continuous centrate return
  - New flowmeter for CCT influent
- Not possible to address all current issues (analyzer accuracy, diurnal variations)

Current Approach - Conclusions

- Compliance with the new permit's ammonia limits with the current control strategy has occurred consistently
- Indicator organism will change in 2014 to more sensitive organism – *E. coli*
  - Current control approach is highly complicated, and events compromising disinfection performance could occur

UV Disinfection Option

- UV is a proven and effective disinfectant
- UV performance is independent of ammonia concentration:
  - Ammonia controlled separately from the disinfection process
- Eliminates the need for dechlorination, thereby eliminating one potential route for permit non-compliance
- Provides the best option for potential future regulatory limits (DBPs, nitrosamines, other pathogen limits, more stringent nutrient limits)
- Part of CDPHE compliance schedule
- At some future time, UV may be required

Potential Difficulties with UV Disinfection

- Compared to monochloramine, UV is more sensitive to water quality excursions (TSS, UVT)
- Power quality changes can result in the UV system being off-line for 5-15 minute periods
- The use of UV disinfection:
  - Reduces the risk for *E. coli* non-compliance
  - Reduces the risk for ammonia non-compliance
  - Eliminates the risk of chlorine non-compliance

What Are Other Colorado Utilities Doing for Wastewater Disinfection?

WWTP	Current Disinfectant	Previous Disinfectant if Known	Annual Average Flowrate	Year Converted
			MGD	
Denver Metro	Sodium Hypochlorite	Chlorine - Gas	140	2010
Colorado Spring Utilities - LVWWTP	UV	Chlorine - Gas	65	2009
Boulder, 75th St WWTP	UV	Chlorine - Gas	25	2011
Fort Collins - Drake WRF	Sodium Hypochlorite	Chlorine - Gas	23	2004
Colorado Springs Utilities - JD Phillips Water Reclamation Plant	UV	New Plant	20	2007
Brighton	UV		18	
Longmont WWTP	UV	Chlorine - Gas	17	2003
Greeley	UV	Chlorine - Gas	14.7	2005
Broomfield	UV	Chlorine - Gas	12	2005
Loveland WWTP	UV	Chlorine - Gas	10	2003
Westminster	UV	Chlorine - Gas	10	2005
Centennial	UV	Chlorine - Gas	8.5	
Fort Collins - Mulberry WRF	UV	Sodium Hypochlorite	6	1997
Plum Creek	UV	Sodium Hypochlorite	5	2004

Assessment of Risk – Existing Data

- Assessment is determined solely from existing WWTP data
- Existing WWTP data incorporates the human element, and the L/E WWTP has a longstanding culture of accomplished WWTP operators doing their best to avoid permit violations
- Quantified risks of non-compliance were very low, although conditions could change in the future
- From the data, probability of compliance (ammonia, *E. coli*, chlorine residual) has been > 99%
- Potential financial penalties of non-compliance are small ($10,000 per day)
- What level of risk is acceptable? The answer varies from utility to utility

Risk Associated with Current Disinfection Approach (from Existing Data)

Option	Ammonia Permit Compliance Risk	E. Coli Permit Compliance Risk	Dechlorination Permit Compliance Risk	Complexity of Operation
Current Approach (NTF Bypass)	0.7%* (1 in 140 Days)	0.9%** (1 in 107 Days)	0.07%*** (1 Day in 4 Years)	High

Notes:

Risk quantification based on existing data, using more stringent criteria than permit language, thus actual risk of permit violation was less than the values shown

Data set analyzed: from 1/1/09 through 4/17/11

* 6 in 837 daily samples had ammonia concentration ≥ 4.0 mg-N/L

** 7 of 750 daily grab samples had *E. coli* levels ≥ 252 per 100 mL

*** 14 of 20120 hourly readings had ORP ≥ 240 mV

Risk Comparison of Disinfection Options

Option	Ammonia Permit Compliance Risk	E. Coli Permit Compliance Risk	Dechlorination Permit Compliance Risk	Safety Issues	Complexity of Operation
Current Approach (NTF Bypass)	0.7% (1 in 140 Days)	0.9% (1 in 107 Days)	0.07% (1 Day in 4 Years)	Medium	High
Modified Current Approach (NTF Bypass with Improvements)	Slightly Lower Risk (Reduced Compared to Current Approach)	Slightly Lower Risk (Reduced Compared to Current Approach)	No Change	No Change	No Change
Preformed Monochloramine	Lower Risk (Reduced Compared to Current Approach)	Lower Risk (Reduced Compared to Current Approach)	No Change	Higher (Additional Chemical Required)	Lower
UV	Lowest Risk (Reduced Compared to Other Options)	Lower Risk (Reduced Compared to Current Approach)	No Risk (Do Not Need to Dechlorinate)	Lower	Lower

Disinfection Option Cost Comparison

TABLE 2 – ESTIMATED COSTS

Option	Capital Cost	Annual Operating Costs
Current Approach with Modifications	$1,200,000	$118,000 / year
Preformed Monochloramine[1]	$2,100,000	$120,000 / year
UV[2]	$7,125,000	$88,000 / year

1. Capital costs represent a Class 4 estimate and include piloting, design, SDCs, and construction of new building for aqueous ammonia storage and feed. Operating costs include costs for 2 mg/L of sodium hypochlorite and 0.5 mg/L aqueous ammonia at an average flow of 23 mgd.
2. Costs for UV were identified in B&C's January 26, 2011 memorandum entitled "Evaluation of Alternative Disinfection Methods to Comply with the Recent Proposed Ammonia Limits". Annual Operating Costs were further refined in March of 2011 by B&C using Ozonia equipment information.

Summary

- Decision should be based on risk, cost, and values
- Current process has consistently met the 2014 ammonia and E. Coli standards
- Risk vs. Cost:
  - UV is the option with lowest risk and highest cost
  - Existing approach with modifications has higher risk, but lower cost
- Values are specific to your community

Littleton/Englewood WWTP Assessment of Existing Disinfection System

Littleton City Council Meeting
June 21, 2011

CH2MHILL

Assessment of the Existing Disinfection System at the Littleton/Englewood Wastewater Treatment Plant

PREPARED FOR: City of Littleton

PREPARED BY: CH2M HILL

DATE: August 1, 2011

PROJECT NUMBER: 421266.03.80.80

Table of Contents

Table of Contents 1
Executive Summary 1
Purpose and Objectives 2
Background 3
NPDES Permit Requirements 3
Chlorine-Ammonia Chemistry 5
Previous Studies 6
Evaluation of Chlorine Disinfection Options Previously Studied 7
Monochloramine Disinfection Using Existing NTF Ammonia Bypass 7
Free Chlorine Disinfection by Breakpoint Chlorination 13
Monochloramine Disinfection using External Ammonia Addition 14
New Disinfection Alternatives for the L/E WWTP 16
Modified Current Approach 16
Preformed Monochloramine 17
UV Disinfection Alternative 19
Future Permit Considerations 20
Potential Difficulties with UV Disinfection 21
UV Disinfection Summary 21
Comparison of Disinfection Options 21
Comparison of Risk 22
Comparison of Cost 25
Summary 26
Appendix A 27

Executive Summary

The Littleton/Englewood Wastewater Treatment Plant (L/E WWTP) has a long and successful track record of providing a high level of wastewater treatment and complying with the plant's discharge limits. The L/E WWTP currently uses chloramine for disinfection and compliance with bacterial discharge limits prior to dechlorination and discharge to the South Platte River.

The objective of CH2M HILL's project for the City of Littleton was to evaluate the feasibility of permit compliance with the continued use of chloramine disinfection. Brown and Caldwell

(B&C) completed the January 26, 2011, Technical Memorandum, entitled "Evaluation of Alternative Disinfection Methods to Comply with the Recent Proposed Ammonia Limits," for the L/E WWTP. This previous project determined that "*the existing system cannot be expected to consistently meet permit limitations based on the newly adopted ammonia and E. coli regulations.*" This document also states that, "*an alternative form of disinfection that does not rely on chlorine and maintains adequate and controllable disinfection is needed.*"

As described in this document, the current disinfection approach used at the L/E WWTP is complex, and there are several modifications that could be made to reduce the complexity, allow more operational flexibility, and reduce the risk of permit violations. Nevertheless, over the 28 months of L/E WWTP operations since the Phase 2 expansion project was completed, there have been no permit violations attributable to the current disinfection approach.

The implementation of UV disinfection at the L/E WWTP offers several benefits, including improved safety, reduced complexity, and the reduction of risk of permit violations in the future. UV disinfection also best positions the L/E WWTP to comply with potential future permit requirements such as disinfection by-products and nitrosamines. However, the cost to implement UV disinfection is approximately $7 million and operation of the current disinfection approach has met the future permit limits for ammonia, *E. coli*, and chlorine residual.

The information provided in the sections of this document that follow should help serve as the basis for decision-making by the City of Littleton (and City of Englewood) on the current need for UV disinfection at the L/E WWTP. The approach ultimately selected for the L/E WWTP should be discussed with CDPHE as soon as possible once the decision is made.

Purpose and Objectives

The Littleton/Englewood Wastewater Treatment Plant (L/E WWTP) has a long and successful track record of providing a high level of wastewater treatment and complying with the plant's National Pollutant Discharge Elimination System (NPDES) discharge limits. The L/E WWTP currently uses chloramine (*i.e.*, chlorine is dosed to the effluent water with ammonia present, forming chloramine as the disinfectant) for disinfection and compliance with bacterial discharge limits prior to dechlorination and discharge to the South Platte River.

The most recent update to the L/E WWTP discharge permit includes more stringent limits for ammonia, as well as new limits for *E. coli* bacteria. The L/E WWTP must comply with the new permit limits by January 1, 2014, meaning that all improvements necessary for continued compliance must be completed by that time. Work completed by others in January 2011 included a comparison of multiple disinfection alternatives to comply with the tiered ammonia limits of the new permit. This work included the recommendation to implement UV disinfection.

The objective of CH2M HILL's project for the City of Littleton was to evaluate the feasibility of permit compliance with the continued use of chloramine disinfection. The work, as described herein, incorporated data analysis, a technical assessment of the existing chlorine-based disinfection system, and consideration of the risks for potential future violations. In summarizing technical details, risk, and cost, the intent was to provide the City of Littleton with the information necessary to select a disinfection approach for the L/E WWTP.

Background

The L/E WWTP is the third largest Publicly Owned Treatment Works (POTW) in the state of Colorado. In 1992, the existing gas chlorine disinfection system at the L/E WWTP was converted to an alternative liquid chlorine system (sodium hypochlorite). The Phase 2 Expansion project, which included improvements to the chlorination and dechlorination systems at the plant, was completed in December 2008, increasing the L/E WWTP capacity to 50 million gallons per day (mgd) on a maximum monthly flow basis. The current facilities dose sodium hypochlorite to denitrification filter effluent with ammonia present for chloramine disinfection, followed by dechlorination with liquid sodium bisulfite prior to discharge.

NPDES Permit Requirements

On September 30, 2009, the L/E WWTP received its NPDES permit renewal, effective November 1, 2009. The current permit expires on October 31, 2014. The L/E WWTP discharges treated effluent to Segment 14 of the South Platte River. The permit includes three parameters that directly influence the choice of which disinfection system to use:

1. Ammonia
2. *E. coli* bacteria
3. Total residual chlorine

The discharge limits for these three parameters are described in the next sections.

Ammonia Limits

The current permit includes ammonia limits, with tiered limits based on average flow from the facility for the calendar month. Daily composite samples serve as the basis for compliance determination. For the 34-mgd tier, the permit limits become more stringent beginning on January 1, 2014 as required by the permit's Compliance Schedule. Beginning in 2014, the 34-mgd tier includes ammonia limits as strict as 4.1 milligram per liter (mg/L), based on a 30-day average, with a daily maximum limit as low as 16 mg/L.

The ammonia limits are even more stringent at the tiers for higher flowrates. For the 50-mgd tier, the most stringent 30-day ammonia limits are for August and September, with a 30-day limit of 3.2 mg/L. The most stringent maximum day limit of 14 mg/L is applicable for March and April. The current and future ammonia limits are shown in Table 1.

TABLE 1
Summary of Littleton-Englewood WWTP Ammonia Limits

	Current Limit (until 12/31/13)		*34 mgd Tier (Outfall 001A)**		*42 mgd Tier (Outfall 001B)*		*50 mgd Tier (Outfall 001C)*	
Month	**30-Day Average+, mg/L**	**Daily Maximum, mg/L**	**30-Day Average+, mg/L**	**Daily Maximum, mg/L**	**30-Day Average+, mg/L**	**Daily Maximum, mg/L**	**30-Day Average+, mg/L**	**Daily Maximum, mg/L**
January	8.7	21.0	8.7	21.0	8.0	20.0	7.6	19.0
February	9.1	20.0	8.5	17.0	7.7	16.0	6.5	15.0
March	7.0	17.5	7.0	16.0	6.6	15.0	6.2	14.0
April	7.0	17.0	7.0	17.0	6.3	16.0	5.3	14.0
May	6.6	23.0	6.6	23.0	5.4	21.0	4.5	19.0
June	6.1	Report	5.9	29.0	5.1	25.0	4.3	23.0
July	5.3	Report	4.4	32.0	4.3	31.0	3.8	29.0
August	4.5	Report	4.2	30.0	3.8	29.0	3.2	28.0
September	4.8	21.0	4.1	24.0	3.8	21.0	3.2	19.0
October	5.8	23.0	5.3	18.0	4.9	17.0	4.1	16.0
November	6.9	18.0	6.3	18.0	5.8	16.0	5.3	16.0
December	11.1	Report	7.3	18.0	6.8	17.0	6.4	16.0
Notes:	* Limits take effect on 1/1/14 per current Compliance Schedule.							
	+ compliance is based on daily composite samples							

E. coli Limits

The current permit includes a bacterial discharge limit based on *E. coli* bacteria. The limits are 30-day average of 126 colony forming units (cfu) per 100 milliliters (mL) and a 7-day average of 252 cfu per 100 mL based on daily grab samples. The *E. coli* limit takes effect on January 1, 2014, based on the Compliance Schedule in the plant's permit. Until then, fecal coliform is the indicator organism, with limits of 245 cfu per 100 mL (30-day average) and 490 cfu per 100 mL (7-day average). All bacterial averages are determined as geometric means.

Total Residual Chlorine Limits

Total chlorine residual is also part of the discharge permit, with essentially no measurable chlorine residual allowed. Five grab samples are to be collected each week, and the 30-day average must be less than 0.0027 mg/L. The daily maximum must be less than 0.024 mg/L at the 34 mgd tier, with slightly tighter limits at the higher flow tiers. No changes to these limits are incorporated in the Compliance Schedule.

Compliance Schedule with CDPHE

The current discharge permit includes a compliance schedule, which is "*required to grant the permittee time to meet the E. coli limitations at all tiers and the ammonia limitations at the 34 mgd tier for the months of Feb, Jun, Jul, Aug, Sep, Oct, Nov and Dec.*" This schedule was worked out with the CDPHE. The timeframe for the compliance schedule was developed assuming the installation of ultraviolent (UV) light disinfection.

A Status/Progress Report was submitted as required on May 31, 2011, to summarize the site application process and approval, design, and progress on approval. The next report is due May 31, 2012, to summarize design and progress on approval. The compliance schedule is based on startup of a new UV disinfection system by the end of 2013.

Chlorine-Ammonia Chemistry

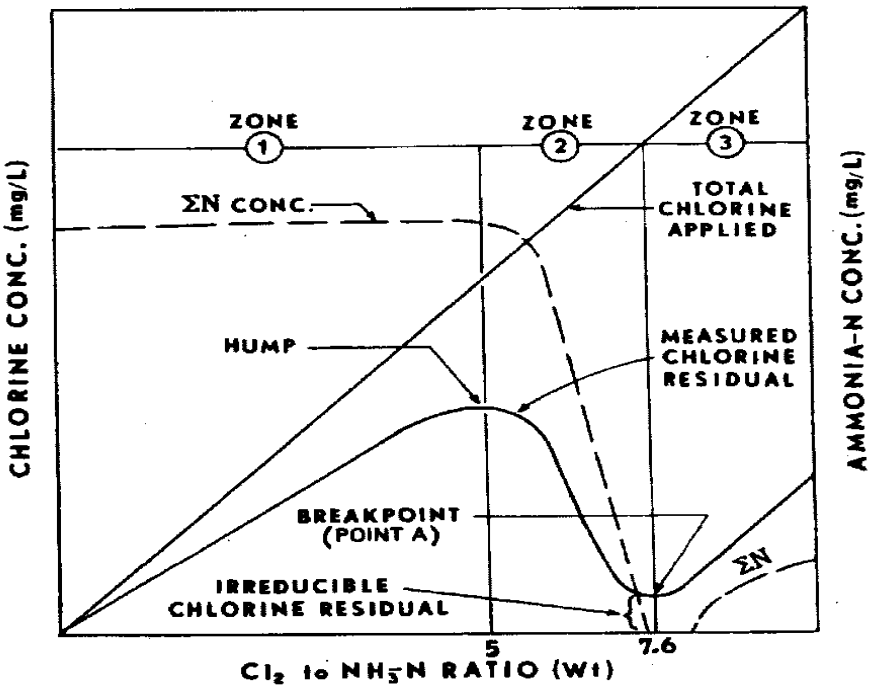
The chemistry of chlorine and ammonia is complicated, but can be successfully managed to disinfect with chloramine. For the L/E WWTP, the desired species of chloramine is monochloramine, which is formed at chlorine-to-ammonia (as nitrogen) weight ratios of less than 5:1.

In Figure 1, a graph illustrating the relationship between chlorine concentration and chlorine-to-ammonia (Cl_2 to NH_3-N) ratio is shown. Key considerations include the following:

- Chlorine/ammonia chemistry is complicated and the correct chemical ratio is required for effective disinfection; for example, application at ratios between 5:1 and 7.6:1 can produce less germicidal chlorine species and a decreasing total chlorine concentration
- Ammonia is present in all domestic wastewater, such as the L/E WWTP influent
- Ammonia must be removed at the L/E WWTP to meet discharge limits
- Ammonia must also be present at sufficient concentrations for effective chloramine disinfection
- These competing objectives can complicate operations in an effort to remove enough but not all ammonia

These considerations will be addressed in more detail in the remaining sections of this document.

FIGURE 1
Chlorine and Ammonia Chemistry



Previous Studies

Brown and Caldwell (B&C) completed the January 26, 2011, Technical Memorandum, entitled "Evaluation of Alternative Disinfection Methods to Comply with the Recent Proposed Ammonia Limits," for the L/E WWTP. This document is referred to as the "Ammonia Compliance Study" throughout the remaining sections of this document. This previous project included evaluation of alternative disinfection methods to comply with future ammonia limits. The Ammonia Compliance Study stated that "*the existing system cannot be expected to consistently meet permit limitations based on the newly adopted ammonia and E. coli regulations.*" This document also states that, "*an alternative form of disinfection that does not rely on chlorine and maintains adequate and controllable disinfection is needed.*"

The previous B&C study evaluated several chlorine disinfection processes in addition to alternative disinfectants such as chlorine dioxide, ozone, peracetic acid, and UV light. From this B&C study, UV disinfection was identified as the preferred disinfection approach based on a monetary and non-monetary evaluation. Key factors in the recommendation of UV disinfection included "*its effectiveness, reliability, low cost (nearly one fourth of the second chosen option, ozone), and other reasons.*"

Following are the primary concerns with chlorine disinfection that were identified in the Ammonia Compliance Study":

- Page 7: "*The issue with very low ammonia concentrations is that the chlorination chemistry becomes unstable and control of the process is very difficult.*"

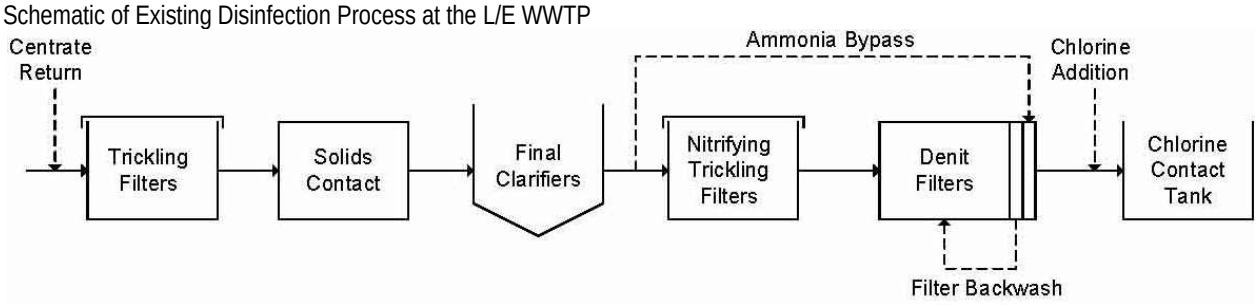
- Page 7: The on-line ammonia analyzers, which are necessary for the chlorine disinfection options identified, are "*difficult to calibrate and do not always produce accurate results.*"
- Page 10: "*If ammonia is added to increase effluent ammonia to adequate levels for chlorination, and nitrification is lost during the month, then violation of the permit limit for ammonia becomes a real risk.*"

As presented in the sections that follow, the intent of this document is to re-evaluate the feasibility of the chlorine disinfection options previously investigated as compared to the selected UV disinfection approach.

Evaluation of Chlorine Disinfection Options Previously Studied

A simplified schematic flow diagram of the existing treatment process at the L/E WWTP is shown in Figure 2. Key system components that contribute to ammonia loading and the disinfection process are depicted. As shown, an ammonia bypass is used to route one to three mgd of secondary effluent that contains ammonia around the nitrifying trickling filters and denitrification (denit) filters. This helps to ensure that sufficient ammonia is present at the point of chlorine addition at the chlorine contact tank influent to form monochloramine.

FIGURE 2
Schematic of Existing Disinfection Process at the L/E WWTP



Brown and Caldwell evaluated three chlorine disinfection strategies as part of the Ammonia Compliance Study:

- Monochloramine disinfection using the existing nitrifying trickling filter (NTF) ammonia bypass
- Free chlorine disinfection by breakpoint chlorination
- Monochloramine disinfection using external ammonia addition

The following sections critically evaluate these potential approaches.

Monochloramine Disinfection Using Existing NTF Ammonia Bypass

Monochloramine disinfection, as currently practiced at L/E WWTP, is accomplished by bypassing secondary effluent around the NTFs to increase the ammonia concentration to approximately 2 mg/L prior to chlorine addition for disinfection. Two potential problems were identified with this approach in the Ammonia Compliance Study:

1) Low secondary effluent ammonia levels in the summer could cause disinfection control issues.

2) Control to the 2 mg/L ammonia setpoint could be difficult due to unreliable ammonia analyzers, despite regular maintenance.

The following analysis investigates these two issues and addresses how reliable this approach has been at meeting the future ammonia and *E. coli* permit limits.

Low Ammonia Levels in the Summer

From the available data set, the lowest measured final effluent ammonia concentration from a daily composite sample was 0.2 mg/L, measured on April 9-10, 2010, and again on December 17, 2010. On those three days, the NTF bypass flow was zero, so the low ammonia levels were the result of no bypassing of flow with higher ammonia content to the denit filter effluent. The next lowest daily ammonia level was 0.4 mg/L, with this value achieved on October 14, 2009, April 8, 2010, and December 16, 2010. On each occasion, the average bypass flow over the course of the day was less than 1.0 mgd, again indicating that consistent ammonia bypass was not provided.

With the exception of the events described above, all other daily composite ammonia concentrations were 0.6 mg/L or higher. With ammonia concentrations of 0.5 mg/L or higher, sufficient ammonia should be present to form monochloramine when chlorine is added at a dose of 2 mg/L (chlorine-to-ammonia ratio of 4:1 or higher). Thus, from the data set, it appears that the ammonia concentrations during the summer were sufficient for effective disinfection control.

Ammonia Control to the 2 mg/L Setpoint

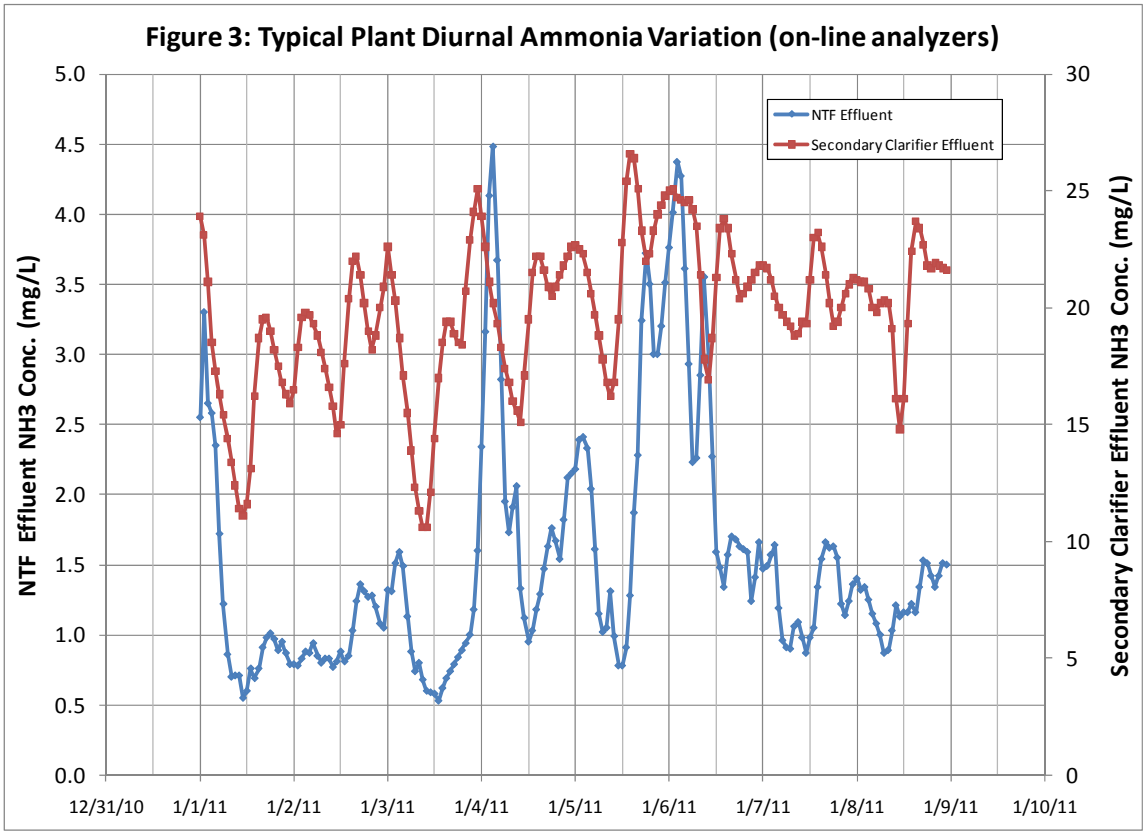
A number of factors impact the measured concentration of ammonia at the chlorine contact tank, which can significantly impact control of the disinfection process:

- **Typical diurnal ammonia variations:** Figure 3 shows the typical diurnal ammonia variation in the secondary effluent and NTF effluent flow streams over the course of one week. One week in January 2011 was selected for presentation purposes, but other periods of the year are similar, although less pronounced during the summer due to higher temperatures. Large and sudden changes are observed twice per day in the secondary effluent with the most prominent occurring from late in the night (near midnight) until mid to late morning. The ammonia concentration during these periods can fall more than 10 mg/L, which is a large and sudden change that requires a similar change to the NTF bypass flow to maintain the 2 mg/L setpoint. Large and sudden changes in process variables are often difficult to control by automated control systems.

- **On-line ammonia analyzer accuracy and reliability:** The on-line ammonia analyzers used for controlling the NTF bypass flow, and consequently the ammonia concentration fed to the chlorine contact tank, are regularly maintained and calibrated by plant staff. However, from observations by L/E WWTP staff, these analyzers can still report incorrect values that cause problems with the disinfection process.

- **Denitrification filter bumping and backwashing:** The denit filters require daily bumping and backwashing with the use of chlorine contact tank influent water. During these events, the flow to the chlorine contact tank is significantly reduced, which causes a dramatic change in the ammonia concentration to the disinfection process. Figure 4

shows the sudden reduction in flow to the chlorine contact tanks ("prechlor flow") during the daily backwash and bumping events.



- **Centrate return pumping:** Centrate from the centrifuges is returned to the head of the plant late at night until early morning. This flow stream has high concentrations of ammonia (>1,000 mg/L) that could cause significant ammonia variations at the chlorine contact tank.

- **NTF bypass control algorithm:** The NTF bypass control algorithm is intended to control the ammonia concentration at the chlorine contact tanks ("prechlor flow") at 2 mg/L by varying the flow rate of the NTF bypass. However, as shown in Figure 5, control at 2 mg/L is not well established and often varies between 1.5 mg/L and 5 mg/L. Changes in the NTF bypass flow rate are often sudden (e.g., instantaneous change from 3 mgd to 0 mgd) which has a large impact on the ammonia concentration to the chlorine contact tank. In addition, the control algorithm does not predict the denit filter bumping and backwash events, nor does it account for potential erroneous measurements from the on-line ammonia analyzers. All of these factors contribute to the inability to reliably control ammonia concentrations at the 2 mg/L setpoint.

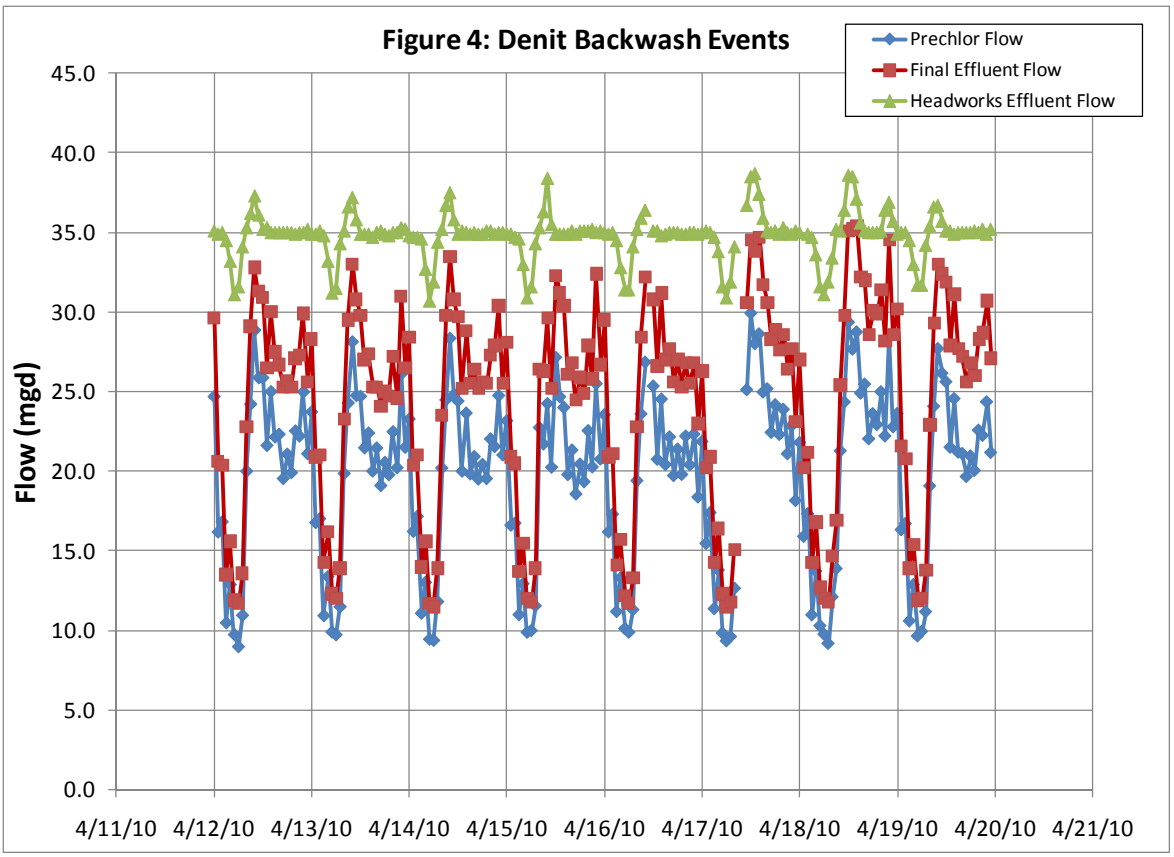


Figure 4: Denit Backwash Events
Prechlor Flow
Final Effluent Flow
Headworks Effluent Flow
Flow (mgd)
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
4/11/10
4/12/10
4/13/10
4/14/10
4/15/10
4/16/10
4/17/10
4/18/10
4/19/10
4/20/10
4/21/10

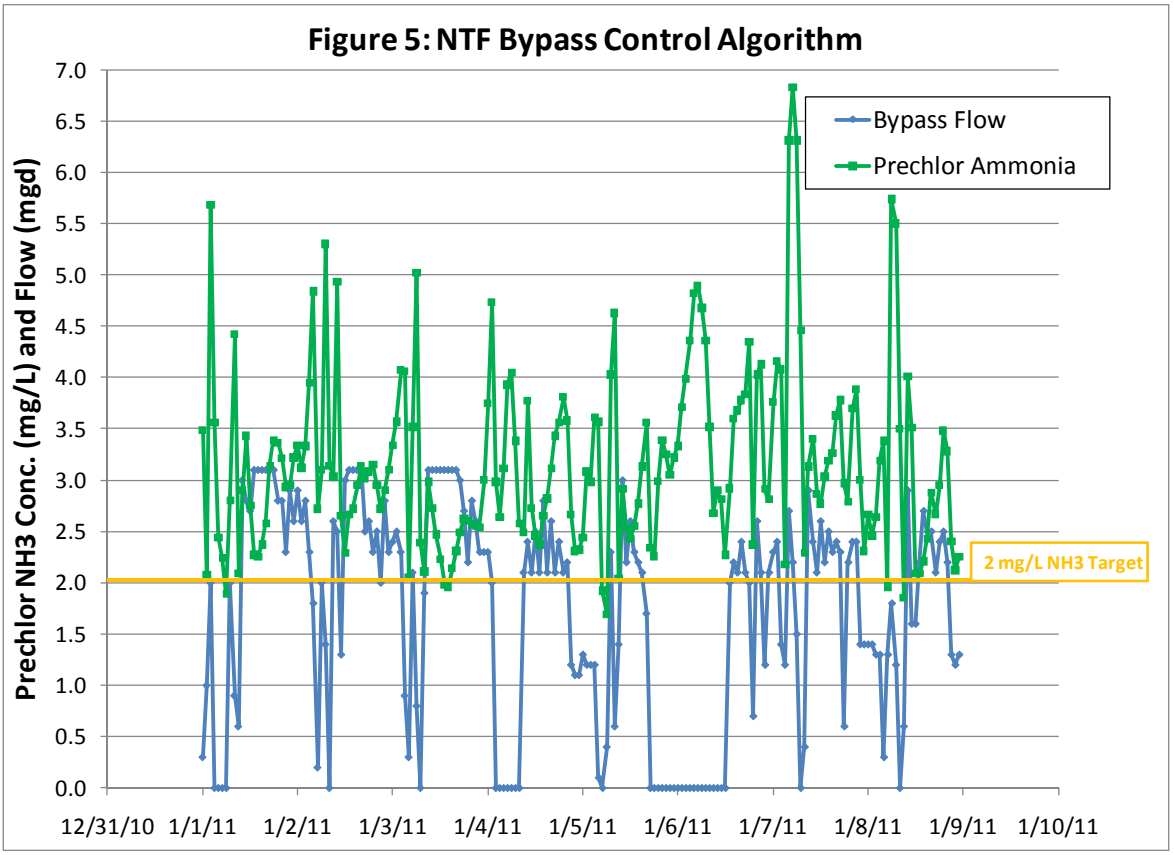


Figure 5: NTF Bypass Control Algorithm
Bypass Flow
Prechlor Ammonia
2 mg/L NH3 Target
Prechlor NH3 Conc. (mg/L) and Flow (mgd)
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
12/31/10
1/1/11
1/2/11
1/3/11
1/4/11
1/5/11
1/6/11
1/7/11
1/8/11
1/9/11
1/10/11

Although control at the 2 mg/L ammonia setpoint is challenging due to the factors described above, the plant has reliably met the future regulatory limits for ammonia and *E. coli*, as described below.

- **Ammonia Permit Compliance:** Figure 6 shows the 30-day average ammonia concentration in the final effluent for the last two years. The maximum 30-day average is approximately 2.5 mg/L with a typical value of approximately 1.5 mg/L. The most restrictive future ammonia limit is 4.1 mg/L at the 34 mgd flow tier during the month of September. The most restrictive future ammonia limit is 3.2 mg/L at the 50 mgd tier. Consequently, despite its significant limitations, the current control strategy has effectively controlled ammonia below the most stringent future permit limits.

- ***E. coli* Compliance:** Figure 7 shows *E. coli* concentrations in the final effluent over the past two years. Daily grab sample data, as well as the 7-day and 30-day geometric means, are shown. Compliance with the future limits has been maintained; however, the plant was severely stressed during the summer months of 2010 with elevated *E. coli* values approaching the future limits. The likely cause of the elevated *E. coli* during this period was inaccurate ammonia measurements by the on-line ammonia analyzers. As shown in Figure 8, which shows a 2-week time period during the summer of 2010, elevated *E. coli* values occurred when the bypass flow dropped to zero, which was likely the response to an increase in the prechlor ammonia concentration. Although the control system was reacting properly, it appears that the on-line ammonia analyzers were reporting incorrect values as evidenced by the fact that the lab reported much lower ammonia values than the on-line ammonia analyzers (0.8 mg/L by lab versus 3 mg/L by on-line analyzers). Consequently, ammonia to the chlorine contact tank was much lower than intended. Thus, it appears that when chlorine was added, the chlorine-to-ammonia ratio was higher than the desired ratio, and a shift in chlorine speciation from monochloramine to a different, much less effective germicidal form such as dichloramine or organochloramine, resulted. This is evidenced by the sudden rise in *E. coli* to 921 cfu/100 mL on May 19, 2010, and to 816 cfu/100 mL on May 27, 2010.

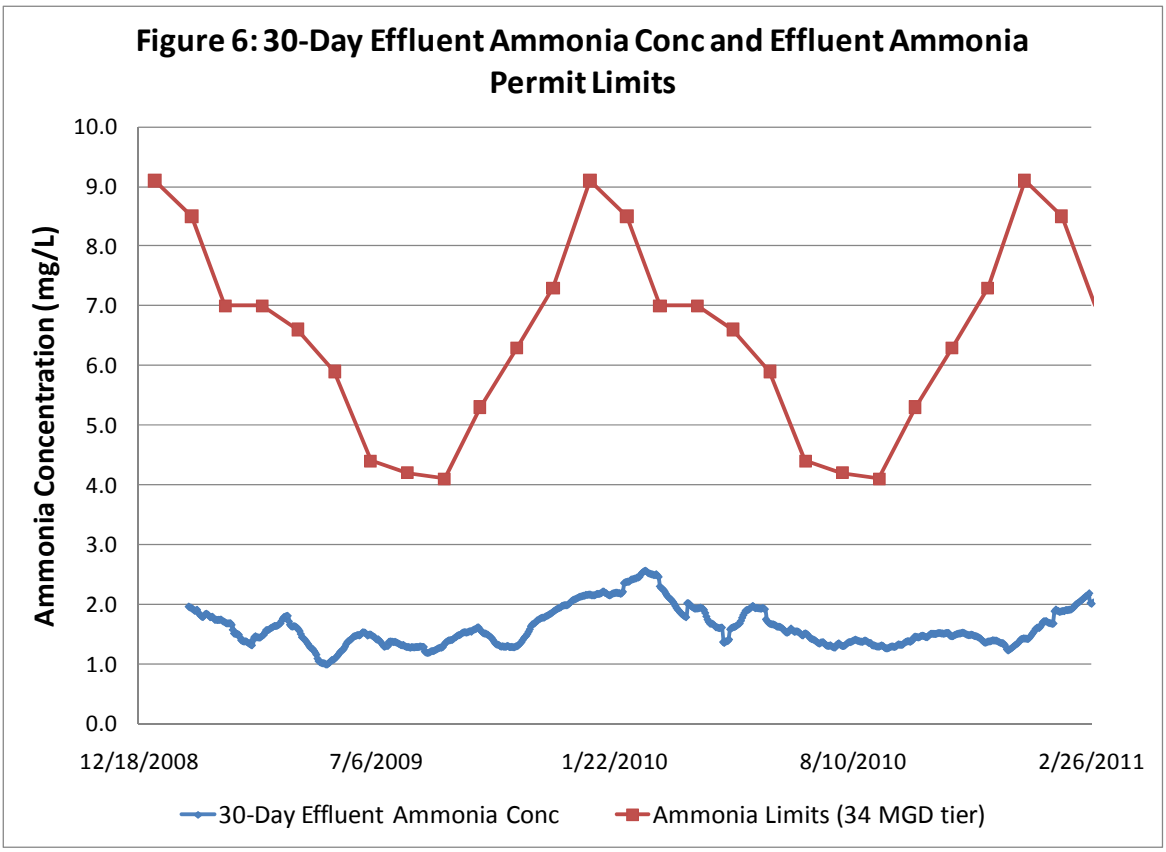


Figure 6: 30-Day Effluent Ammonia Conc and Effluent Ammonia Permit Limits
Ammonia Concentration (mg/L)
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
12/18/2008
7/6/2009
1/22/2010
8/10/2010
2/26/2011
30-Day Effluent Ammonia Conc
Ammonia Limits (34 MGD tier)

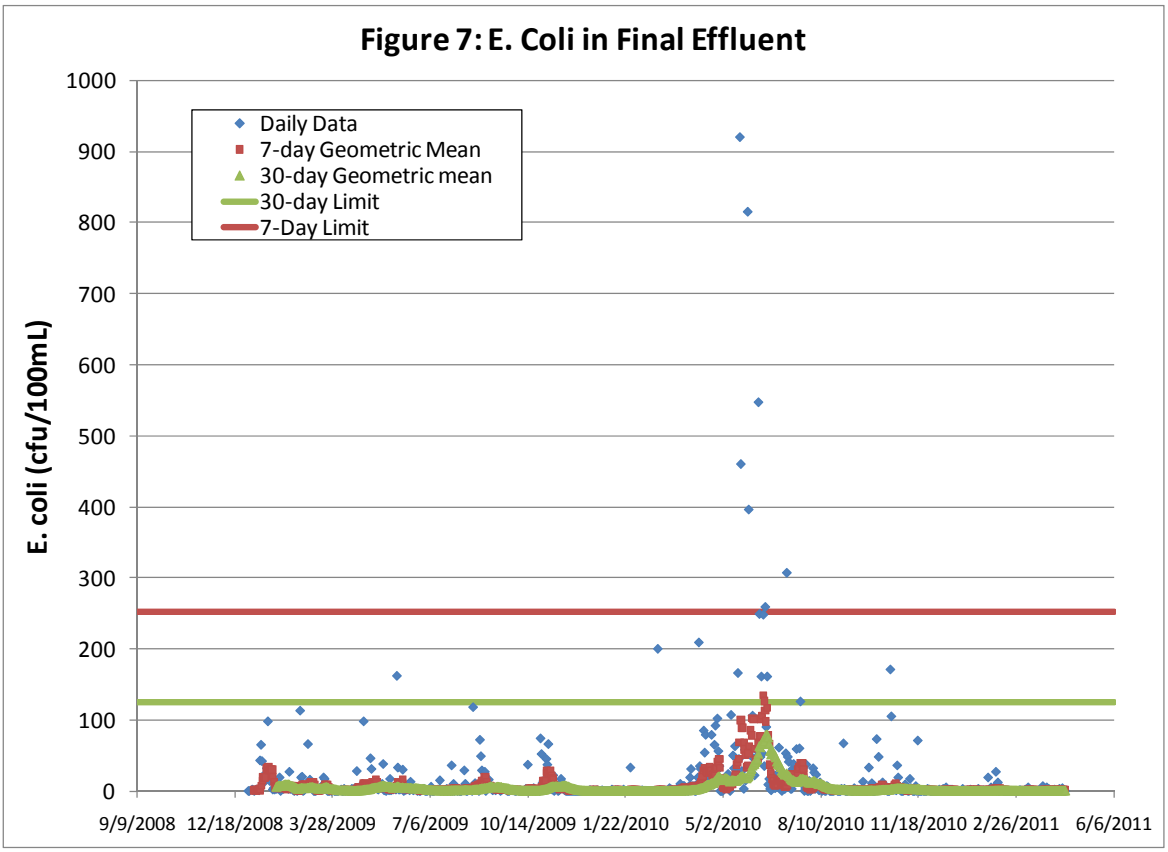
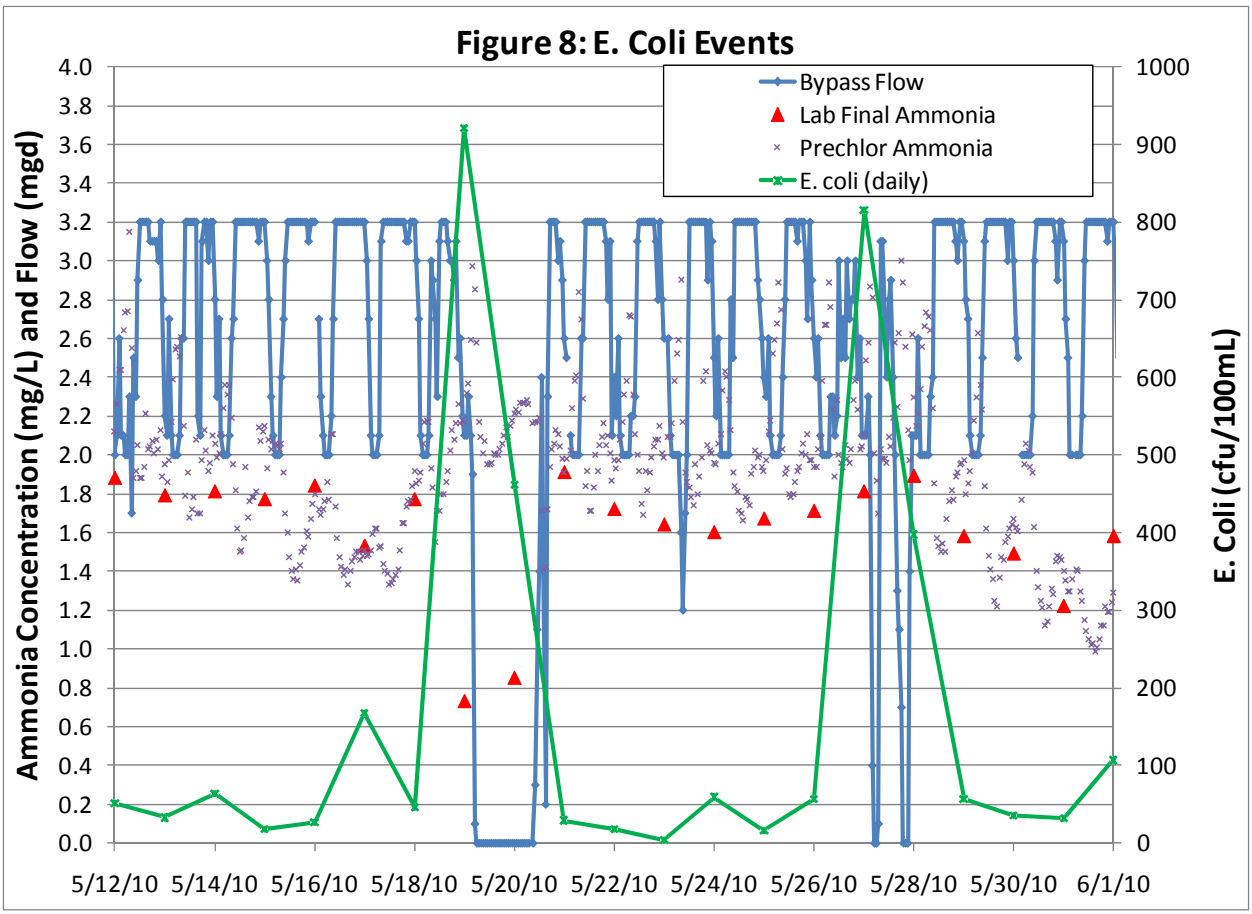


Figure 7: E. Coli in Final Effluent
E. coli (cfu/100mL)
1000
900
800
700
600
500
400
300
200
100
0
Daily Data
7-day Geometric Mean
30-day Geometric mean
30-day Limit
7-Day Limit
9/9/2008
12/18/2008
3/28/2009
7/6/2009
10/14/2009
1/22/2010
5/2/2010
8/10/2010
11/18/2010
2/26/2011
6/6/2011

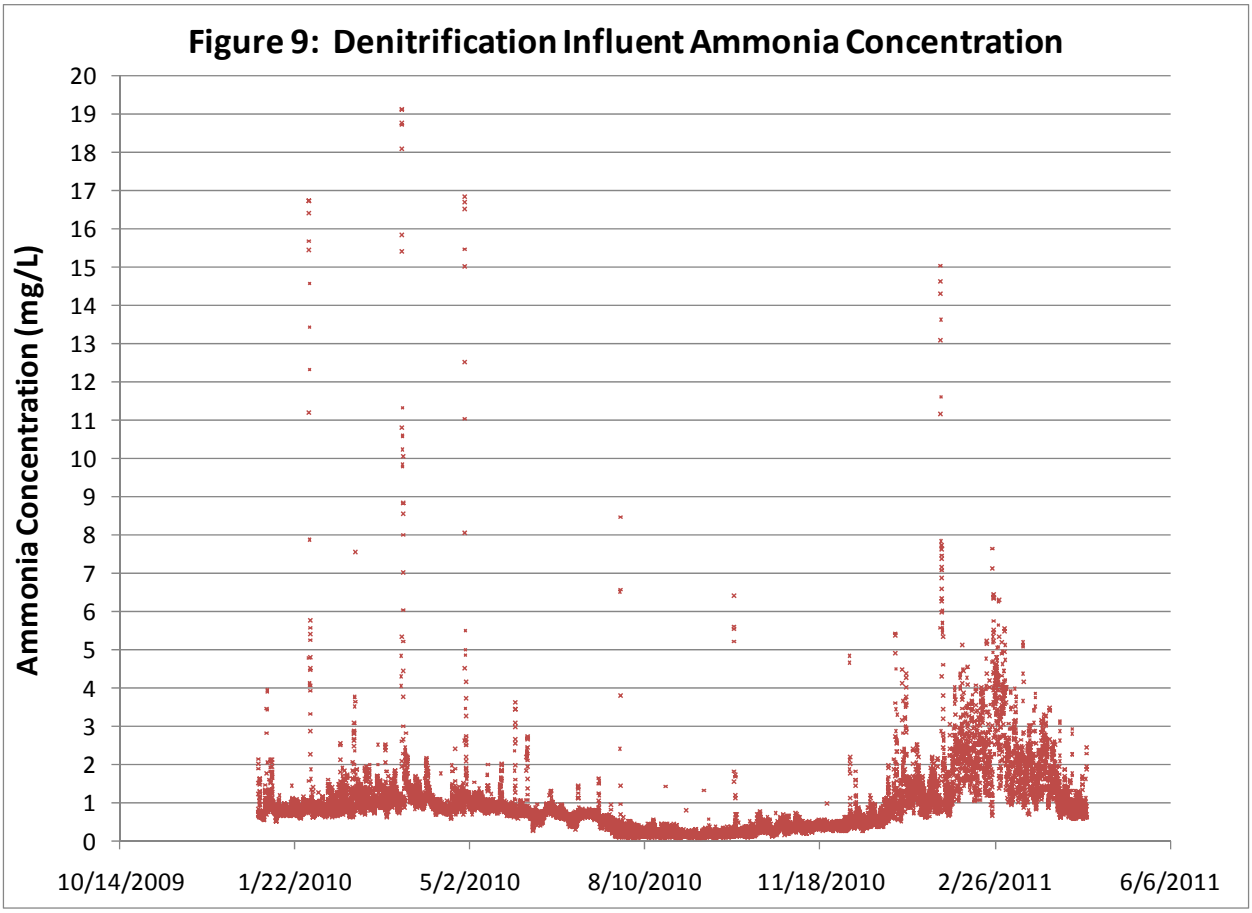


Free Chlorine Disinfection by Breakpoint Chlorination

This approach incorporates a "breakpoint chlorination" strategy in which enough chlorine is added to the chlorine contact tank influent to completely oxidize all ammonia present, thus producing a free chlorine residual for disinfection. This represents the region of very high chlorine-to-ammonia ratios (greater than 10:1) in Figure 1. With this approach, the NTF bypass would not be used.

In practice, breakpoint chlorination typically requires approximately 10 parts of chlorine per part of ammonia-nitrogen present to create a free chlorine residual. Consequently, the chlorine dose required for operation of this process is completely dependent on the ammonia present in the water. Figure 9 shows the concentration of ammonia in the denit filter influent, which is a good representation of what would be present in the chlorine contact tank influent with no ammonia bypass. As seen on this figure, the ammonia concentration is typically between 0.1 mg/L and 2 mg/L, meaning a chlorine dose between 1 mg/L and 20 mg/L would be necessary to create a free chlorine residual. In addition, the ammonia concentration periodically spikes to values above 10 mg/L, suggesting a loss in the nitrification process (plant staff suggests that this might be caused by inhibitors in the raw wastewater). During these periods a chlorine dose in excess of 100 mg/L would be required to achieve breakpoint, and the dose change would have to be rapid, possibly beyond the capabilities of the control system. Chlorine concentrations in the chlorine contact tank effluent could also vary widely in a rapid fashion which would

make dechlorination problematic with potential violations in meeting the current permit limits for total residual chlorine.



Other disadvantages with the breakpoint chlorination approach including significantly increased chlorine use, and thus, higher costs, additional equipment needs to address turndown requirements, and chlorine off-gassing. Because of the numerous disadvantages associated with this approach, it is not recommended for further consideration for implementation.

Monochloramine Disinfection using External Ammonia Addition

This approach includes the addition of ammonia from an external source (*i.e.*, anhydrous ammonia or aqueous ammonia) to allow reliable control of a monochloramine residual for disinfection. The NTF bypass would not be operated in this approach. Three potential problems were identified with this approach in the Ammonia Compliance Study. Analysis of each of these potential problems is addressed in the following:

- **<u>Issue #1</u>**
    - *Problem:* Page 10: "*Besides natural diurnal variations in effluent ammonia levels, the denite filter backwash has instantaneous effects on the flow and loads which may easily cause further ammonia excursions… A control system involving sophisticated feed-back loops would be required and, even then, the chance for chlorine, E. coli, or ammonia permit violations would be unacceptably high.*"

- *Analysis:* Diurnal ammonia variations could significantly impact control of an ammonia feed system when targeting a specific ammonia concentration (e.g., 2 mg/L). In addition flow variations caused by denitrification backwashes could cause problems meeting the ammonia limit (if ammonia is overfed), the *E. coli* limit (if ammonia or chlorine are underfed), and the chlorine limit (if chlorine is overfed) if flow measurement is not accurate.

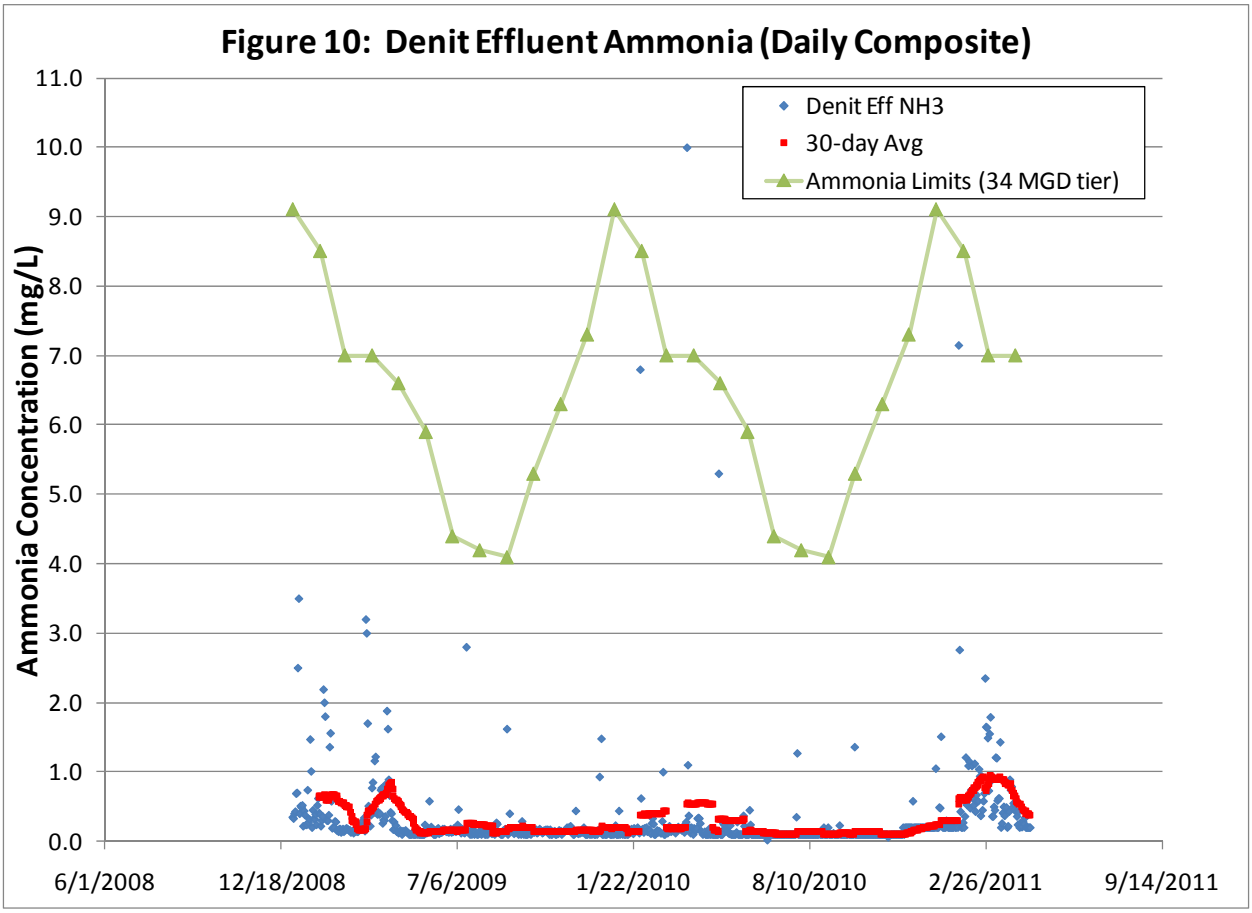
- **Issue #2**
  - *Problem:* Page 10: "*If ammonia is added to increase effluent ammonia to adequate levels for chlorination, and nitrification is lost during the month, then violation of the permit limit for ammonia becomes a real risk*."
  - *Analysis:* As shown in Figure 10, the 30-day average ammonia concentration in the denitrification effluent never exceeded 1.0 mg/L. Because a maximum of only 1 mg/L of ammonia addition should be necessary to ensure monochloramine formation[1], the maximum 30-day average ammonia concentration in the data set analyzed would only be 2 mg/L which is below the most stringent future regulatory requirement in the month of September (4.1 mg/L at 34 mgd, 3.8 mg/L at 42 mgd, and 3.2 mg/L at 50 mgd). However, reliable control using on-line ammonia analyzers at a setpoint of 2 mg/L for the NTF Bypass approach has proved problematic (see earlier discussion). Consequently, although this approach would theoretically meet the ammonia effluent limits, analytical measurement limitations increase the risk associated with its implementation. Modifications are possible to increase reliability; however, a similar but more robust alternative chloramine disinfection approach presented later in this memorandum holds more merit.

- **Issue #3**
  - *Problem:* Page 10: "*A further disadvantage of ammonia addition to maintain disinfection with chloramine species, is the formation of nitrosamines in the effluent*."
  - *Analysis:* Nitrosamines can form in significant quantity when using chloramines for disinfection of wastewater effluent. However, formation is very dependent on the specific water quality and the manner in which chloramine disinfection is practiced. Consequently, nitrosamine formation potential bench testing should be conducted if concern exists. Nitrosamines are currently not included in the L/E WWTP effluent permit and it is unknown if they will be included in the next permit review cycle. Some states, including California and Arizona, have included n-nitrosodimethylamine (NDMA) in some permits for wastewater discharges.

Although implementation of the external ammonia addition process could potentially be successful, limitations in the analytical instruments in effectively controlling this process increase the risk of potential problems. The next section addresses the use of preformed monochloramine. This approach offers the advantages of monochloramine disinfection using

[1] Adding 1 mg/L ammonia would be the maximum needed when dosing monochloramine at 4 mg/L (conservative dose) to achieve a Cl2:NH3-N weight ratio of 4:1

external ammonia addition, plus additional advantages and less risk of problems. Therefore, disinfection using external ammonia addition is not recommended for further consideration.



New Disinfection Alternatives for the L/E WWTP

The previous sections examined three disinfection options for the L/E WWTP that were previously evaluated as part of the Ammonia Compliance Study. As part of CH2M HILL's work for the City of Littleton, two new options were identified, as follows:

- Modified current approach
- Preformed monochloramine

The two new options are described in the following sections.

Modified Current Approach

The previous sections of this document described the complexity of the current approach, as well as the factors that contribute to changes in ammonia levels at the point of chlorine addition. The "Modified Current Approach" consists of continuing to use the ammonia bypass and liquid hypochlorite addition (and dechlorination), but with some modifications implemented to improve operational flexibility and reduce the complexity of operation. Five specific modifications that would achieve these objectives were identified. These modifications, ranked in order of priority for implementation, are as follows:

- Modifications to the control algorithm to dampen the response to potentially inaccurate on-line ammonia measurements and to proactively address flow changes caused by bumping and backwashing of the denitrification filters.
- Bypass pump modifications to allow pumping of lower bypass flowrates
- Installation of a new flowmeter for the chlorine contact tank influent to ensure an accurate flow measurement for disinfection
- Modifications to the denitrification backwash tank to eliminate the large, sudden changes in flows due to denitrification filter backwashing and bumping
- Installation of a larger centrate tank to allow return of centrate flow over a longer period of time each day

Each of these improvements is conceptual in nature at this time. Additional evaluation is recommended to develop further detail for each concept.

Preformed Monochloramine

Monochloramine is currently formed at the Littleton-Englewood WWTP "in-situ"; in other words, sodium hypochlorite added to the denitrification effluent mixes with the ammonia present in the water to form monochloramine within the bulk flow. A recent innovation in wastewater disinfection technology is to preform monochloramine outside the bulk flow and then apply the "preformed monochloramine" to the bulk flow for disinfection. In this process, sodium hypochlorite and aqueous ammonia are mixed in careful proportion to ensure formation of the desired, germicidal monochloramine. From the perspective of disinfection performance, this is preferable to attempting to form monochloramine in the bulk water, which can lead to the formation of other chlorine species that are not effective disinfectants (e.g., dichloramine and organochloramine). This approach may offer several advantages at the L/E WWTP:

- A chlorine dose of 1.5 – 2.0 mg/L, which is a typical chlorine dose based on historical L/E WWTP data, only requires the addition of approximately 0.5 mg/L of ammonia to the water when preforming monochloramine. This is significantly less than the ammonia added with the current NTF Bypass approach that controls to an ammonia concentration of 2 mg/L even when ammonia is very low in the nitrification effluent. Based on the data shown in Figure 10, the maximum 30-day average effluent ammonia concentration should only increase to about 1.5 mg/L, which is well below the new permit limits.
- Control of the preformed monochloramine process is not dependent on the plant's diurnal ammonia fluctuations and the accuracy of on-line ammonia analyzers, both of which have caused problems with the current NTF Bypass approach and the external ammonia addition approach described above. In the preformed monochloramine approach, sodium hypochlorite and aqueous ammonia are mixed outside of the bulk flow in precise amounts using feed pumps and magnetic flow meters to ensure proper formation of monochloramine prior to injection to the denit filter effluent. Consequently, there is no interference from the ammonia variations in the bulk water or inaccuracy from the on-line ammonia analyzers.

- Since the preformed monochloramine approach uses monochloramine for disinfection, its disinfection efficacy should be equivalent to or better than the NTF Bypass approach.
- Preformed monochloramine has been shown to produce significantly less nitrosamines than formation of monochloramine within the bulk water, although this should be tested in the lab before implementation.

Figure 11 shows a process flow diagram of how the preformed monochloramine approach would be implemented at the L/E WWTP. Much of the existing equipment and infrastructure could be reused. New equipment would include aqueous ammonia storage tanks, feed pumps, and ancillary equipment and analyzers. Softened water would also be necessary for dilution and mixing of the sodium hypochlorite and aqueous ammonia. If implemented, new equipment would be located in a new building adjacent to the existing sodium hypochlorite building or possibly inside the existing sodium bisulfite building if space exists. The significant flow variations caused by the denitrification backwash, as discussed above, would have to be addressed to ensure consistent and accurate chemical feed. Possible options to address this issue include installation of a more reliable flow meter on the 84-inch diameter SE pipe, modification to the control programming to anticipate the backwash events, and construction of a larger backwash supply tank.

CH2M HILL has recently implemented preformed monochloramine at a 19 mgd advanced reuse plant in Australia and we have just completed design of another for a plant in Arizona. Performance at the plant in Australia has been good; however, its application was to prevent membrane biofouling instead of disinfection. Therefore, if there is interest in implementing this process at the L/E WWTP, piloting is recommended to prove disinfection efficacy and controllability. Piloting would also allow operators to become familiar with the approach prior to full-scale implementation. Sampling for nitrosamine analysis would also be recommended to quantify formation amounts and potential impacts to future regulations. This would also be the first application of preformed monochloramine in the State of Colorado, so it would require approval from CDPHE.

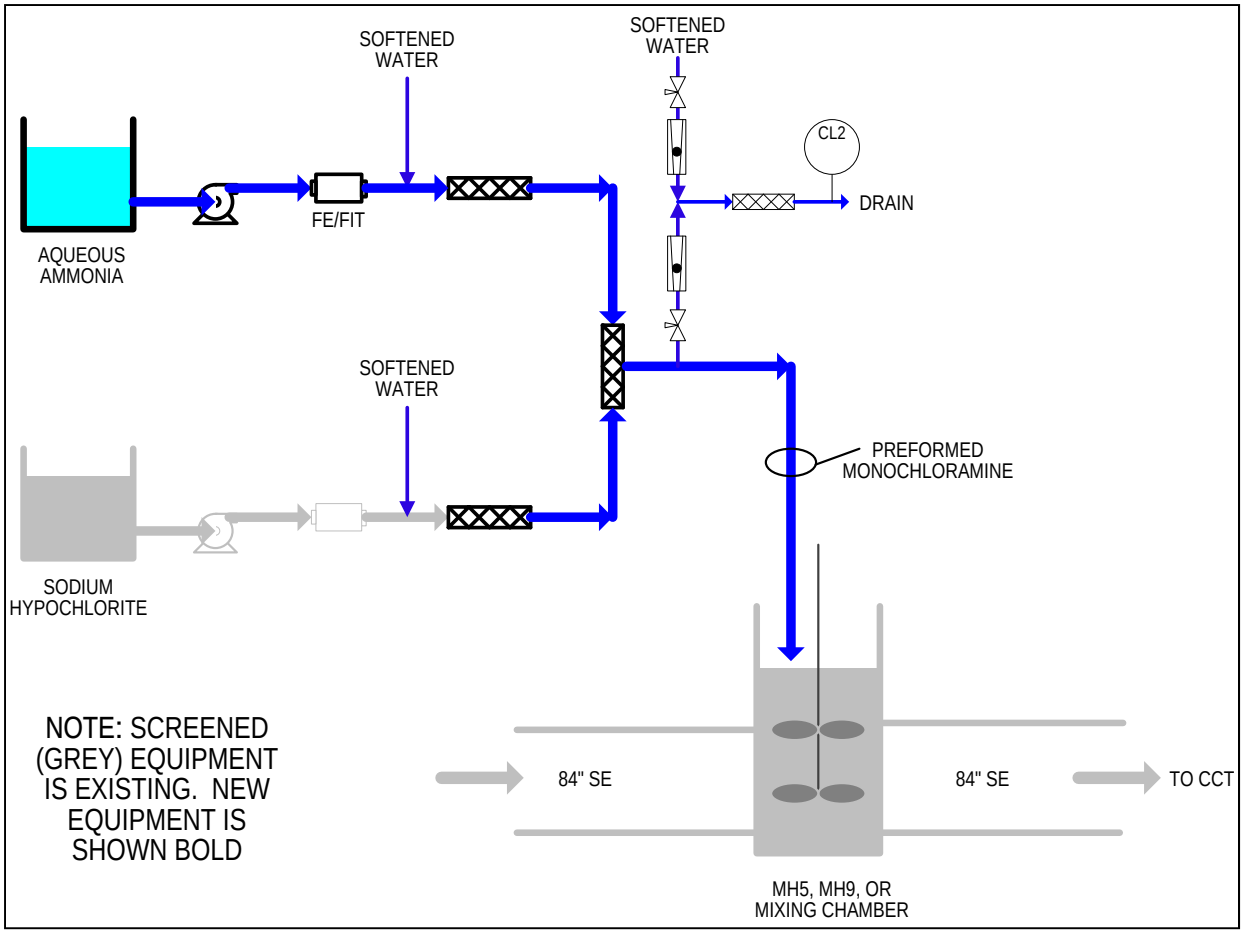


Figure 11: Preformed Monochloramine Feed System

UV Disinfection Alternative

Based on the previous "Ammonia Compliance Study," UV disinfection was recommended for implementation. UV disinfection is a viable, state-of-the-art disinfection technology that could provide effective disinfection at the L/E WWTP, assuming robust design criteria and sound engineering and construction. UV disinfection is a proven approach, with a track record of use for wastewater disinfection since the 1980s. Pilot testing of UV disinfection was recently conducted at the L/E WWTP. As summarized in the B&C Technical Memorandum of November 18, 2010, entitled, "UV Disinfection System Pilot Testing," the two UV systems tested were effective at inactivating fecal coliform and *E. coli* bacteria.

Unlike the chlorine and chloramine disinfection options described previously in this document, UV disinfection performance is independent of ammonia concentration. Thus, ammonia can be controlled separately from the disinfection process, and ammonia can be removed to the greatest extent possible through treatment at the L/E WWTP. The current NTF bypass can be turned off, with no bypass flow. The implementation of UV disinfection would also eliminate the need for dechlorination, thereby eliminating one potential route for permit non-compliance.

A summary of the disinfection systems used by other larger WWTPs in Colorado is shown in Table 2. As shown, two of the larger WWTPs in Colorado continue to use chlorine as a

disinfection chemical. However, 12 other facilities in Colorado treating average flows of 5 mgd or higher currently use UV disinfection.

TABLE 2
Summary of Disinfection Approaches at Colorado WWTPs

WWTP	Current Disinfectant	Previous Disinfectant if Known	Annual Average Flowrate	Year Converted
			MGD	
Denver Metro	Sodium Hypochlorite	Chlorine - Gas	140	2010
Colorado Spring Utilities - LVWWTP	UV	Chlorine - Gas	65	2009
Boulder, 75th St WWTP	UV	Chlorine - Gas	25	2011
Fort Collins - Drake WRF	Chlorine - Gas	-	23	-
Colorado Springs Utilities - JD Phillips Water Reclamation Plant	UV	New Plant	20	2007
Brighton	UV		18	
Longmont WWTP	UV	Chlorine - Gas	17	2003
Greeley	UV	Chlorine - Gas	14.7	2005
Broomfield	UV	Chlorine - Gas	12	2005
Loveland WWTP	UV	Chlorine - Gas	10	2003
Westminster	UV	Chlorine - Gas	10	2005
Centennial	UV	Chlorine - Gas	8.5	
Fort Collins - Mulberry WRF	UV	Sodium Hypochlorite	6	1997
Plum Creek	UV	Sodium Hypochlorite	5	2004

Future Permit Considerations

The L/E WWTP discharge permit has been updated on a five-year cycle. The next cycle is anticipated to consist of an update to the NPDES discharge permit issued in Fall 2014. If time is required to implement new facilities in order to achieve compliance, CDPHE can, at their discretion, grant additional time to complete the associated improvements. Thus, based on precedence, new permit requirements would not be expected to have to be met until January 2019.

In the future, it is possible that the L/E WWTP may need to comply with additional discharge permit limits addressing trihalomethanes, nitrosamines, specific pathogens, or more stringent ammonia limits, all of which impact the disinfection selection process. In some cases, the inclusion of a specific contaminant in sampling conducted for a Pre-Treatment Program may accelerate the regulation of that contaminant.

The L/E WWTP Pre-Treatment Program parameters include the trihalomethane species: bromoform, chlorodibromomethane, chloroform, and dichlorobromomethane. These trihalomethanes (THMs) are disinfection by-products (DBPs) formed by free chlorine contact in wastewater.

The Pre-Treatment Program parameters also include N-nitrosodimethylamine (NDMA), N-nitrosodi-n-propylamine, and N-nitrosodiphenylamine. These parameters are part of the group of contaminants known as nitrosamines. Nitrosamine formation has been attributed to several factors, including the use of chloramination, particularly in wastewater.

In addition, DBPs are covered by limits in the EPA's Federal Toxics Rule, so over time the L/E WWTP may be required to meet limits for specific DBPs, such as trihalomethanes.

Thus, future permit limits could include DBPs such as THMs, nitrosamines, new pathogens, or more strict ammonia limits. UV disinfection provides the best option for meeting the potential future regulatory limits for DBPs, nitrosamines, and more strict ammonia limits. UV disinfection will also reduce risk of *E. coli* non compliance compared to the current disinfection approach. At some future time, UV disinfection may be necessary to meet discharge limits at the L/E WWTP. The need for UV disinfection could occur as soon as 2019, or later, depending on national and state-wide regulatory developments.

Potential Difficulties with UV Disinfection

To provide a UV disinfection system that reliably complies with the *E. coli* limits, the design criteria must be selected to provide sufficient conservatism. UV disinfection is sensitive to water quality excursions such as increases in total suspended solids (TSS) and decreases in the UV transmittance (UVT) of the wastewater. In addition, power quality changes can result in the UV system being off-line for 5 to 15 minute periods, even when a backup generator is provided.

Typical industry practice is to require the UV equipment system manufacturer to validate the performance of UV disinfection equipment through biodosimetric testing. From our review of the work completed to date on the project, it does not appear that the specifications for the selected UV equipment include a requirement for validation testing.

The water quality design criteria and demonstration of dose capability of the UV disinfection system were already specified. Additional water quality data should be collected over time to better understand the level of conservatism incorporated in the design criteria. CH2M HILL also recommends working with the selected UV manufacturer to quantify the validated dose, based on biodosimetry testing with MS-2 phage, on a reduction equivalent dose (RED) basis. Power quality data from the L/E WWTP and from the selected UV manufacturer can be used to gain a better understanding of the extent of potential power quality-related disruptions to disinfection. These additional analyses will allow a more thorough understanding of the conservatism incorporated in the UV disinfection system design.

UV Disinfection Summary

With the adoption of sufficiently conservative UV disinfection design criteria, the use of UV disinfection will reduce the risk for *E. coli* non-compliance as compared to the current disinfection approach. In addition, the use of UV disinfection will allow ammonia removal to be maximized (including elimination of NTF bypass) at the L/E WWTP, thereby reducing the risk for ammonia non-compliance. UV disinfection will also completely eliminate the risk of chlorine residual non-compliance.

Comparison of Disinfection Options

As described in the preceding sections of this document, the four most feasible disinfection options are:

1. Current Approach
2. Modified Current Approach (continued use of current approach, with improvements)
3. Preformed Monochloramine
4. UV Disinfection

A comparison of these four options is presented in this section. Both risk and cost are addressed to facilitate this comparison. In addition, the community values and priorities need to be incorporated into the decision process as the City of Littleton (and the City of Englewood) moves forward in selecting the disinfection approach.

Comparison of Risk

Staff from the L/E WWTP provided data for the time period from January 1, 2009, through April 17, 2011. This time period was selected because it began once construction of the Phase 2 expansion project was completed.

The assessment of risk completed for this project was determined solely from existing L/E WWTP data. The risk numbers shown in this section are not predictions, instead they are calculations performed using the existing plant data.

It should be noted that the L/E WWTP has a longstanding culture of accomplished WWTP operators doing their best to avoid permit violations. Thus, the number of permit violations in the data set analyzed has been minimized because the operators have done everything possible to avoid violations. Over this time period, the quantified risks of non-compliance were very low, although previous performance is no guarantee of future performance, and conditions could change in the future.

Another important consideration is the question, "What level of risk is acceptable?" The answer to this question varies from utility to utility, based on the mission, vision, and guiding principles of the utility. Therefore, the cities of Littleton and Englewood must decide for themselves what level of risk is acceptable at the L/E WWTP.

In Table 3, the risk quantification is shown based on the existing data. From the data, the probability of compliance with permit limits for ammonia, *E. coli*, and total chlorine residual has been greater than 99 percent. It should be noted that the risk numbers shown in Table 3 were quantified using more stringent criteria than the actual permit language, thus the actual risk of permit violation was less than the values shown. In fact, over the time period evaluated, there were no events in which the 2014 permit limits for ammonia, *E. coli*, or total residual chlorine were exceeded based on the permit compliance calculation methods. The risk values shown in Table 3 use more conservative criteria than the actual permit language in order to better illustrate the risk and facilitate discussion of the disinfection alternatives.

TABLE 3
Risk Associated with Current Disinfection Approach (from Existing Data)

Option	Ammonia Permit Compliance Risk	E. Coli Permit Compliance Risk	Dechlorination Permit Compliance Risk
Current Approach (NTF Bypass)	**0.7% (1 in 140 Days)**	**0.9% (1 in 107 Days)**	**0.07% (1 Day in 4 Years)**

Note: Data set analyzed was from 1/1/09 through 4/17/11.

In Table 3, the ammonia permit compliance risk was determined by comparing the ammonia concentrations from the daily composite samples with an ammonia limit of 4.0 mg/L. From the data set, 6 in 837 daily samples had an ammonia concentration $\geq$ 4.0 mg/L. It should be noted that, beginning in January 2014, the most strict ammonia limit for the 34-mgd tier is 4.1 mg/L, based on a 30-day average.

The *E. coli* permit compliance risk was determined by comparing the *E. coli* levels in daily grab samples with an *E. coli* level of 252 cfu per 100 mL. This *E. coli* level represents the maximum allowable 7-day level based on a geometric mean calculation starting in 2014. From the data set, 7 of 750 daily grab samples had *E. coli* levels $\geq$ 252 cfu per 100 mL.

The dechlorination permit compliance risk was determined by comparing oxidation-reduction potential (ORP) measurements to a value of 240 milli-Volts (mV). From discussion with L/E WWTP operations staff, it is anticipated that the daily permit limit for total residual chlorine would be exceeded if ORP were to be greater than or equal to 240 mV. A total of 20,120 hourly readings were considered, and 14 of those readings had an ORP of 240 mV or higher.

Potential Penalties for Non-Compliance

The Water Quality Control Division (Division) of the Colorado Department of Public Health and Environment (CDPHE) can take enforcement action when they believe a violation of an order, permit, or control regulation has occurred. It is at the discretion of the Division how they proceed with an enforcement action. Typically, for a violation of the permit terms and conditions, including a violation of an effluent limitation, the Division will send a letter notifying the permittee of the violation. If there are multiple or ongoing violations, or non-responsiveness to the original letter, then the Division could issue a Notice of Violation (NOV), which would be the initiation of a formal enforcement action. However, the Division could issue a NOV after just one instance of a violation. After the NOV, the Division will then issue a Cease and Desist Order (CDO) that identifies the corrective actions and deadline for achieving compliance. Additionally, the Division could issue the NOV and CDO at the same time as a single notification. The issuance of the NOV and CDO are the first phase of an enforcement action.

The second phase of an enforcement action would include the settlement negotiations and imposition of penalties. Civil penalties could be as much as $10,000 per day of violations. The Division will calculate the civil penalties taking into account potential damage, degree of fault, and history of non-compliance. The final penalty is typically negotiated between the Division

and the violator. If a significant economic benefit has been realized by the violation then the Division could also add to the penalty the amount of the benefit.

In addition to civil penalties, the Colorado Revised Statutes allow for prosecution of criminal penalties when a person recklessly, knowingly, intentionally, or with criminal negligence discharges pollutants to state waters due to a violation of a permit. Criminal penalties are also monetary fines that can range up to $25,000 per day of violations. Knowingly making false statements in any documents or knowingly rendering inaccurate any monitoring equipment is a misdemeanor and upon conviction will be punished by a fine of no more than $10,000 or imprisonment for up to six months, or both.

The federal Clean Water Act also allows for both civil and criminal penalties per the NPDES. Federal criminal penalties for negligent violations can be as much as $25,000 per day of violation and/or imprisonment for up to one year. Federal criminal penalties for any person who knowingly violates can be as much as $50,000 per day of violation and/or imprisonment for up to three years.

Comparison of Other Factors

In Table 4, a comparison of the four disinfection options is presented. The risk values shown for the Current Approach are identical to the values shown in Table 3. The safety issues for the current approach are shown as "Medium," because of the use and handling of liquid hypochlorite. The complexity of operation is shown as "High" based on the information described previously in this document.

The Modified Current Approach includes improvements that result in slightly lower risk of non-compliance for ammonia and *E. coli*, as well as less complex operation.

Preformed Monochloramine reduces the risk of non-compliance for ammonia and *E. coli*, results in less complex operation, but increases safety issues by introducing the need for storage, handling, and use of aqueous ammonia at the plant.

UV Disinfection has the lowest risk for non-compliance for ammonia, a reduced risk of non-compliance for *E. coli* compared to the Current Approach, while also eliminating the risk of non-compliance with the total residual chlorine limit. In addition, UV Disinfection improves safety issues, significantly reducing chlorine handling and use on-site, and improves the complexity of operation.

TABLE 4
Comparison of Disinfection Options

Option	Ammonia Permit Compliance Risk	E. Coli Permit Compliance Risk	Dechlorination Permit Compliance Risk	Safety Issues	Complexity of Operation
Current Approach	0.7% (1 in 140 Days)	0.9% (1 in 107 Days)	0.07% (1 Day in 4 Years)	Medium	High
Modified Current Approach (with Improvements)	Lower Risk (Reduced Compared to Current Approach)	Lower Risk (Reduced Compared to Current Approach)	No Change	No Change	Lower
Preformed Monochloramine	Lower Risk (Reduced Compared to Current Approach)	Lower Risk (Reduced Compared to Current Approach)	No Change	Higher (Additional Chemical Required)	Lower
UV Disinfection	Lowest Risk (Reduced Compared to Other Options)	Lower Risk (Reduced Compared to Current Approach)	No Risk (Do Not Need to Dechlorinate)	Lower	Lower

Comparison of Cost

The estimated capital and operating costs for these four approaches are shown in Table 5. As shown, UV disinfection is the most expensive of the four options. The savings in operating costs for the UV disinfection option of approximately $30,000 per year compared to the other options equate to a present worth value of less than $500,000 per year.

TABLE 5
Comparison of Disinfection Options

Option	Capital Cost	Annual Operating Costs
Current Approach with No Modifications	$0	$118,000 / year
Current Approach with Modifications[1]	$1,200,000	$118,000 / year
Preformed Monochloramine[2]	$2,100,000	$120,000 / year
UV[3]	$7,125,000	$88,000 / year

1. Cost includes all five potential improvements. Subsets of the five improvements could be implemented at reduced cost.
2. Capital costs represent a Class 4 estimate and include piloting, design, SDCs, and construction of new building for aqueous ammonia storage and feed. Operating costs include costs for 2 mg/L of sodium hypochlorite and 0.5 mg/L aqueous ammonia at an average flow of 23 mgd.
3. Costs for UV were provided by City of Littleton and developed by others. Annual Operating Costs are based on site-specific information provided by Ozonia, the selected equipment manufacturer for the L/E WWTP.

For the costs shown in Table 5, it should be noted that the annual operating costs do not include labor. It is expected that there would not be differences in the number of full-time equivalent staff required for the four disinfection options.

Information provided by the City of Littleton, and developed by others, included an annual operations and maintenance (O&M) cost for the current approach of $165,000 per year. Of that total, $47,000 consisted of general O&M costs including labor such as routine operator checks for 3 hours per day. This cost of $47,000 per year was excluded from the costs shown in Table 4 because similar categories were not included for the other alternatives. Of the $118,000 per year shown in Table 4, $89,000 per year is for chemicals.

The UV costs developed by others include an estimated capital cost of $6.9 million to implement the project, plus $250,000 already spent. The UV O&M estimate, developed by others includes energy use, replacement of lamps and some other components, and lamp sleeve cleaning O&M, including labor. General daily labor, such as routine operator checks, does not appear to be included.

Summary

As described in this document, the current disinfection approach used at the L/E WWTP is complex, and there are several modifications that could be made to reduce the complexity, allow more operational flexibility, and reduce the risk of permit violations. Over the 28 months of L/E WWTP operations since the Phase 2 expansion project was completed, there have been no permit violations attributable to the current disinfection approach.

The implementation of UV disinfection at the L/E WWTP offers several benefits, including improved safety, reduced complexity, and the reduction of risk of permit violations in the future. UV disinfection also best positions the L/E WWTP to comply with potential future permit requirements such as DBPs and nitrosamines. However, the cost to implement UV disinfection is approximately $7 million and operation of the current disinfection approach has met the future permit limits for ammonia, *E. coli*, and chlorine residual.

The information provided in this document should help serve as the basis for decision-making by the City of Littleton (and City of Englewood) on the current need for UV disinfection at the L/E WWTP. The approach ultimately selected for the L/E WWTP should be discussed with CDPHE as soon as possible once the decision is made.

The presentation handout from the most recent presentation to the Littleton and Englewood City Councils on June 28, 2011, is included as Appendix A of this document.

Appendix A

Littleton/Englewood WWTP Assessment of Existing Disinfection System

Special Meeting
June 28, 2011

CH2MHILL

Background – Previous Work by Others

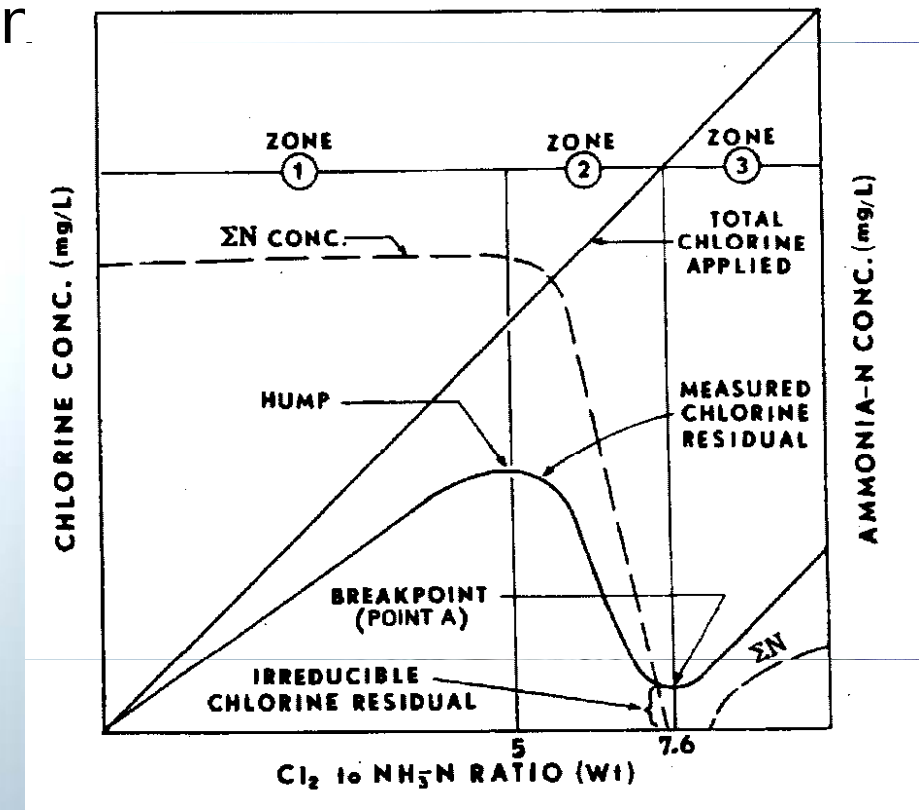
- B&C previously evaluated the existing system and alternative disinfection methods to comply with future ammonia limits.
- Previous finding for the existing disinfection approach:
  - "cannot be expected to consistently meet permit limitations" based on newly adopted discharge limits for the WWTP
- Identified UV disinfection as the selected alternative
- Ammonia Compliance Schedule approved by CDPHE and included in WWTP's discharge permit

Background – Previous Work by Others

- Previous work recommended UV disinfection based on following concerns with chlorine disinfection options:
  - Low ammonia concentrations complicate chlorination chemistry
  - Difficult process control
  - On-line ammonia analyzers, which are necessary for the chlorine disinfection options, are difficult to calibrate and do not always produce accurate results
  - Options with ammonia *addition* may increase risk of future permit violation
- The intent of CH2M HILL's study is to re-evaluate the feasibility of the chlorine disinfection options

Why Is Ammonia Important for Disinfection at the L/E WWTP?

- Ammonia is present in wastewater
- Ammonia must be removed to meet discharge limits
- Ammonia must be present at sufficient concentrations for effective chlorine disinfection
- Competing objectives result in a balancing act to remove enough but not all ammonia
- Chlorine/ammonia chemistry is complicated: the correct chemical ratio is required for effective disinfection

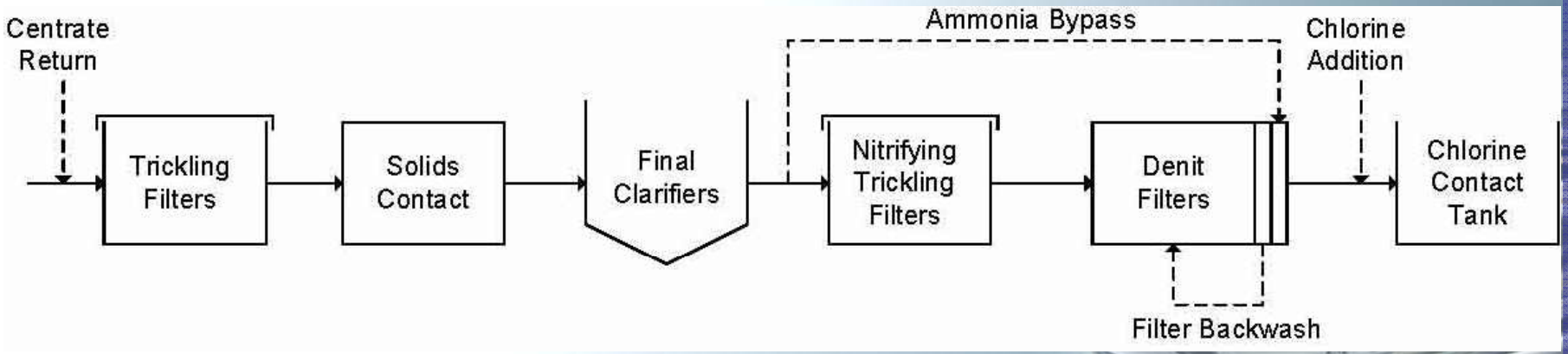


Evaluation of Chlorine Disinfection Options Previously Considered

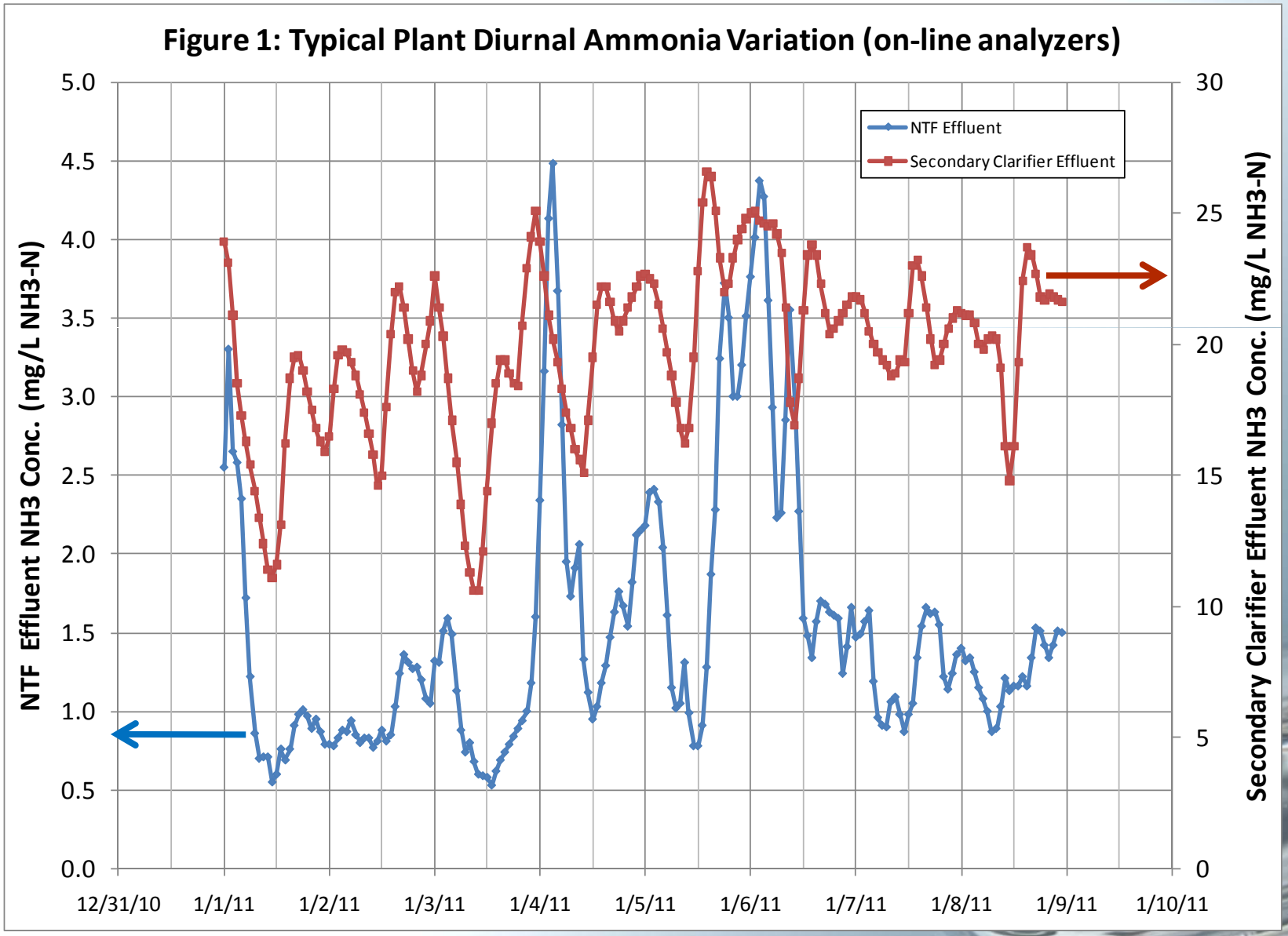
- **Option #1:** Free chlorine disinfection by breakpoint chlorination – high chlorine dose, high cost, not controllable, not recommended
- **Option #2:** Monochloramine disinfection using existing NTF Bypass
- **Option #3:** Monochloramine disinfection using external ammonia addition – higher cost than Option 2, no additional advantages

Difficulties with Current Approach

- Current approach bypasses some ammonia around nitrification
- Other plant operations complicate the process
  - Typical diurnal ammonia variations
  - On-line ammonia analyzer accuracy and reliability
  - Denit filter bumping and backwashing
  - NTF bypass control algorithm
  - Centrate return pumping

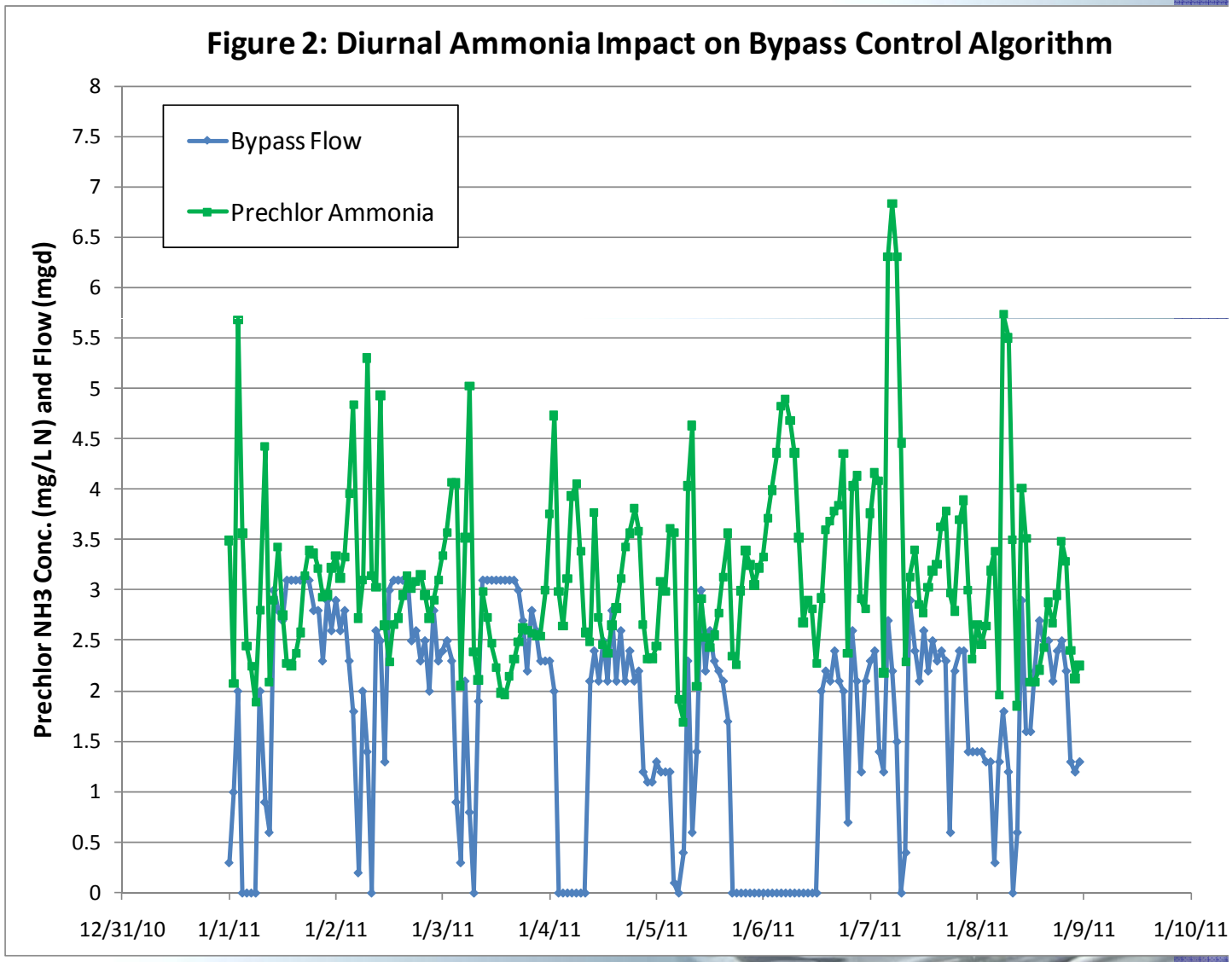


Ammonia Varies Significantly through the WWTP



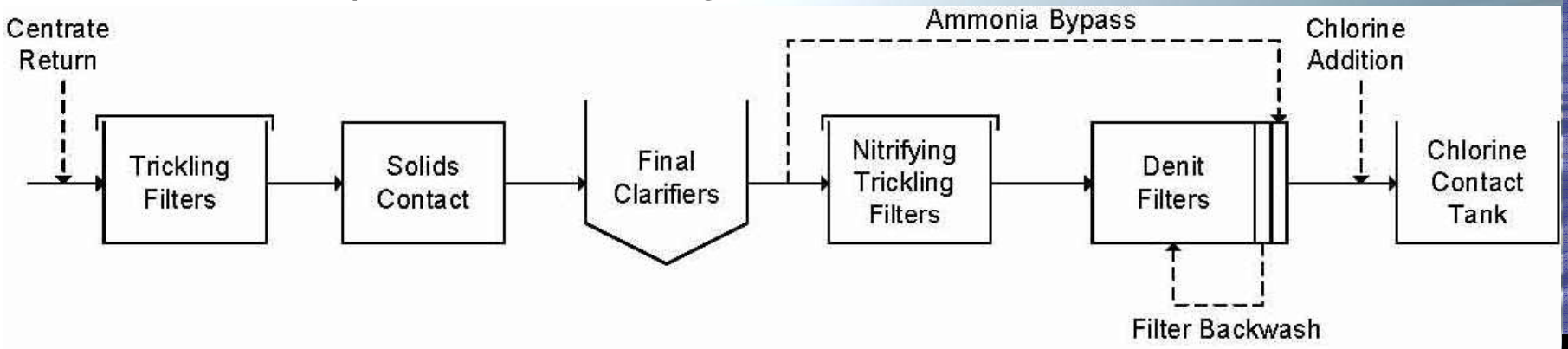
Ammonia Variations through the Plant Can Significantly Impact Control of the Disinfection Process

- Control at 2 mg/L not effective
- Prechlor ammonia varies from 1.5 to 5 mg/l
- Bypass flow varies between 0-3 mgd



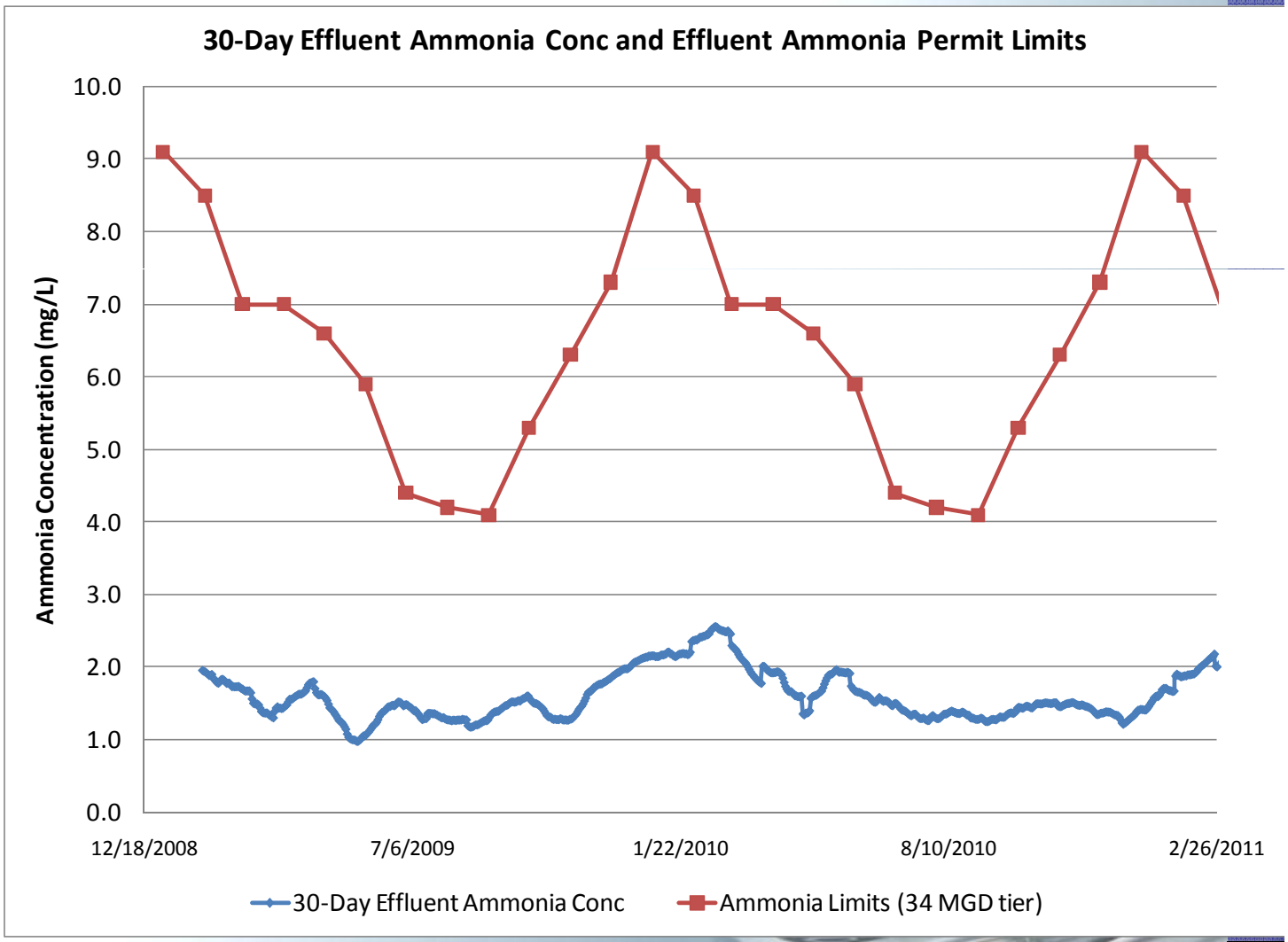
Difficulties with Current Approach

- Typical diurnal ammonia variations
- Denit filter bumping and backwashing
  - Large sudden flow variations
  - Rapid change in ammonia concentration
- Centrate pumping:
  - Sudden increase in ammonia concentration in NTF bypass
- NTF bypass control algorithm
  - Over-reacts to ammonia changes
  - Doesn't predict flow changes from backwash events



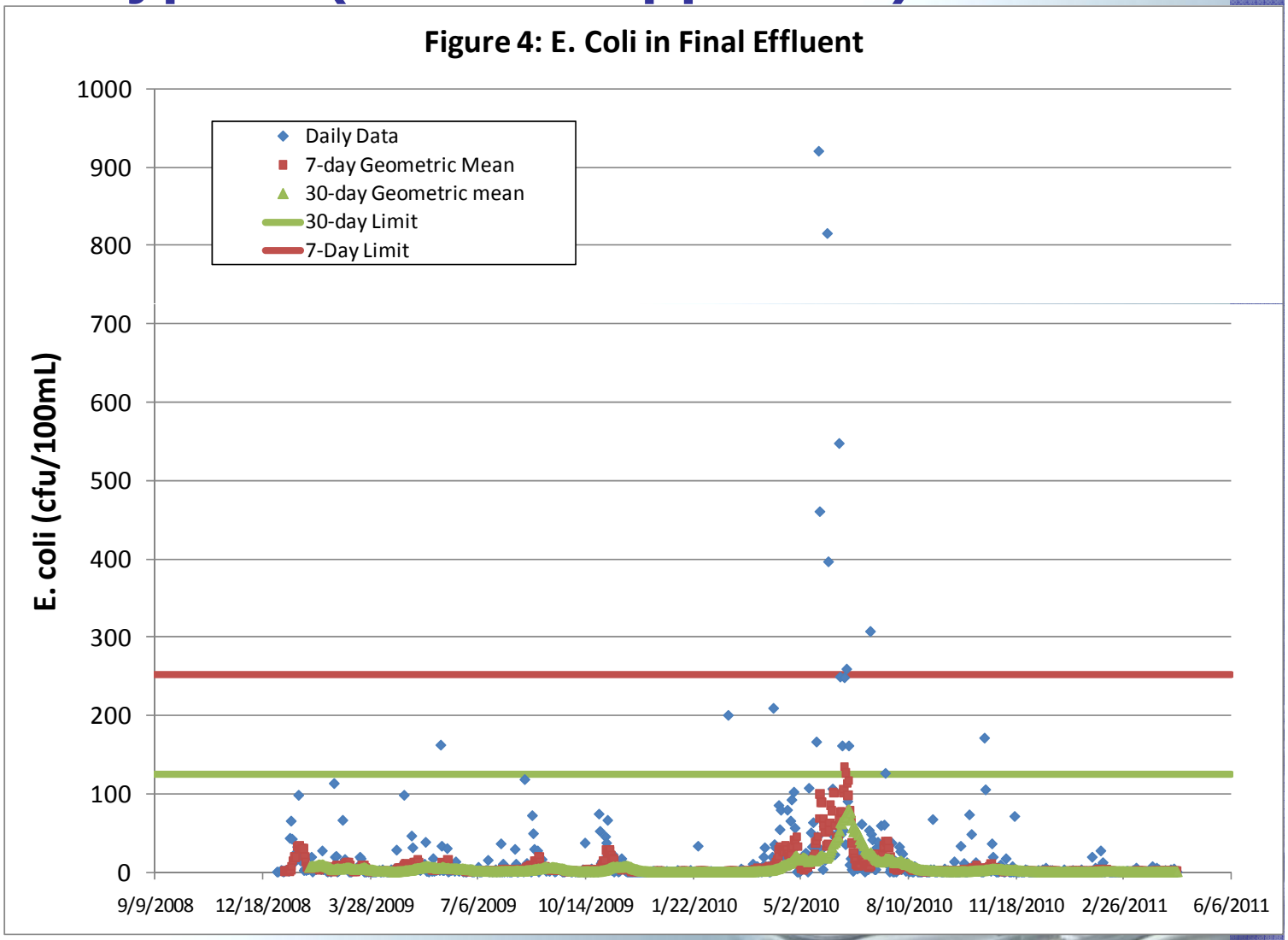
Ammonia Compliance with Future Regulations Using NTF Bypass (Current Approach)

- The most restrictive future ammonia limit is 3.2 mg/L (50 mgd, September)
- Compliance with future ammonia requirements has occurred
- Periodic inhibition events are problematic, but are more disruptive to ammonia compliance than disinfection



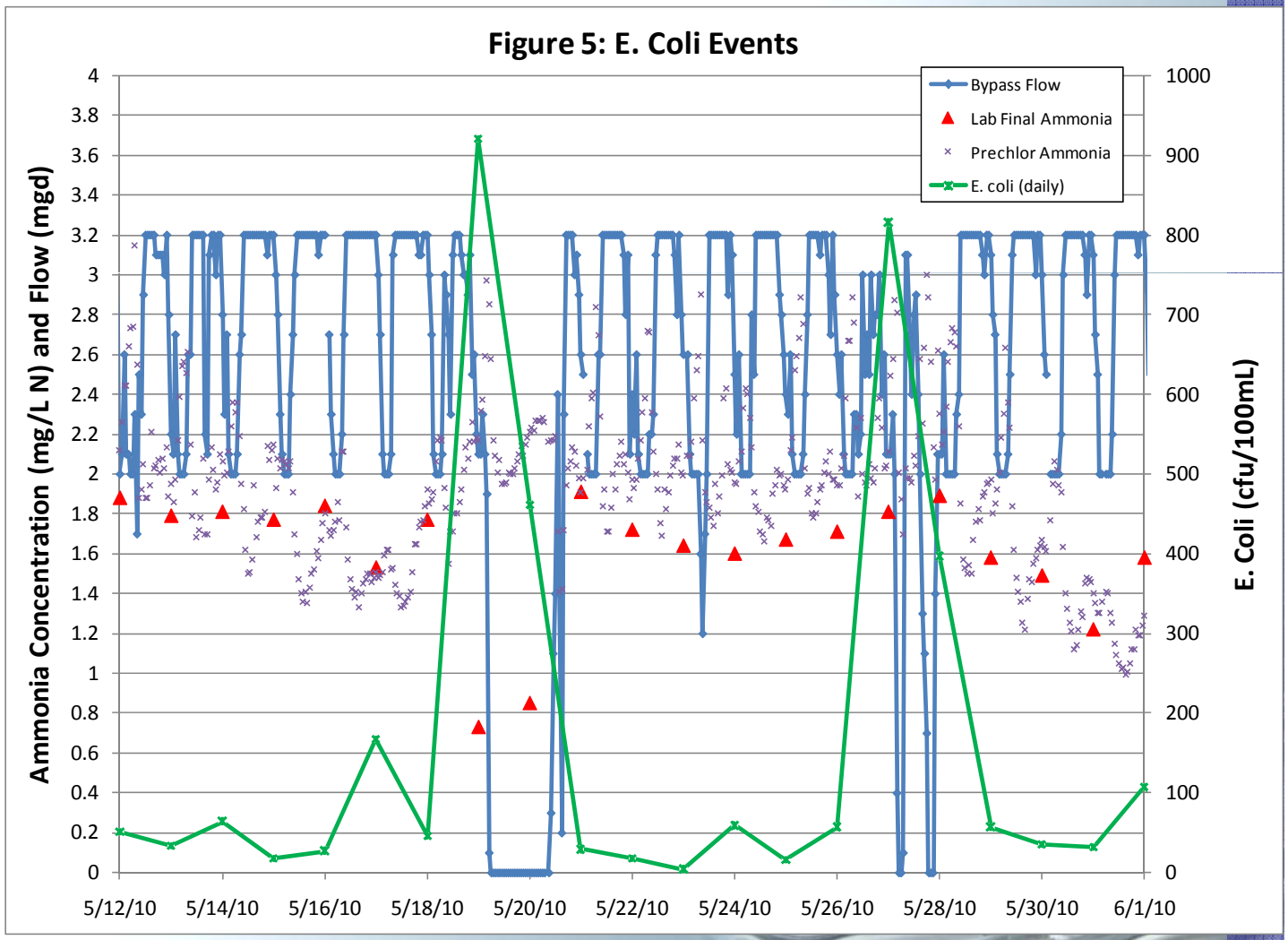
E. Coli Compliance with Future Regulations Using NTF Bypass (Current Approach)

- *E. Coli* limit will be more difficult to meet than fecal coliform
- Performance is generally good
- Almost exceeded future limits in summer of 2010



What Caused Elevated *E. coli* Levels in Summer 2010?

- Two *E. coli* "events" caused by erroneous on-line ammonia analyzer; (0.8 mg/L by lab versus 3 mg/L by on-line analyzers)
- Consequently, ammonia to the CCT was much lower than intended; resulted in formation of less germicidal chlorine species



Summary of Current Approach

- Objectives:
  - 1. Compliance with ammonia limit
  - 2. Disinfection (bacterial indicator organism compliance)
  - 3. Dechlorination
- Operators have done an excellent job achieving compliance with complicated system and numerous variables
- Potential improvements to current approach:
  - Control improvements
  - Dampening of bypass flow, replace pump for minimum flow
  - Off-line denit filter backwash supply
  - Continuous centrate return
  - New flowmeter for CCT influent
- Not possible to address all current issues (analyzer accuracy, diurnal variations)

Current Approach - Conclusions

- Compliance with the new permit's ammonia limits with the current control strategy has occurred consistently
- Indicator organism will change in 2014 to more sensitive organism – *E. coli*
  - Current control approach is highly complicated, and events compromising disinfection performance could occur

UV Disinfection Option

- UV is a proven and effective disinfectant
- UV performance is independent of ammonia concentration:
  - Ammonia controlled separately from the disinfection process
- Eliminates the need for dechlorination, thereby eliminating one potential route for permit non-compliance
- Provides the best option for potential future regulatory limits (DBPs, nitrosamines, other pathogen limits, more stringent nutrient limits)
- Part of CDPHE compliance schedule
- At some future time, UV may be required

Potential Difficulties with UV Disinfection

- Compared to monochloramine, UV is more sensitive to water quality excursions (TSS, UVT)
- Power quality changes can result in the UV system being off-line for 5-15 minute periods
- The use of UV disinfection:
  - Reduces the risk for *E. coli* non-compliance
  - Reduces the risk for ammonia non-compliance
  - Eliminates the risk of chlorine non-compliance

What Are Other Colorado Utilities Doing for Wastewater Disinfection?

WWTP	Current Disinfectant	Previous Disinfectant if Known	Annual Average Flowrate	Year Converted
			MGD	
Denver Metro	Sodium Hypochlorite	Chlorine - Gas	140	2010
Colorado Spring Utilities - LVWWTP	UV	Chlorine - Gas	65	2009
Boulder, 75th St WWTP	UV	Chlorine - Gas	25	2011
Fort Collins - Drake WRF	Sodium Hypochlorite	Chlorine - Gas	23	2004
Colorado Springs Utilities - JD Phillips Water Reclamation Plant	UV	New Plant	20	2007
Brighton	UV		18	
Longmont WWTP	UV	Chlorine - Gas	17	2003
Greeley	UV	Chlorine - Gas	14.7	2005
Broomfield	UV	Chlorine - Gas	12	2005
Loveland WWTP	UV	Chlorine - Gas	10	2003
Westminster	UV	Chlorine - Gas	10	2005
Centennial	UV	Chlorine - Gas	8.5	
Fort Collins - Mulberry WRF	UV	Sodium Hypochlorite	6	1997
Plum Creek	UV	Sodium Hypochlorite	5	2004

Assessment of Risk – Existing Data

- Assessment is determined solely from existing WWTP data
- Existing WWTP data incorporates the human element, and the L/E WWTP has a longstanding culture of accomplished WWTP operators doing their best to avoid permit violations
- Quantified risks of non-compliance were very low, although conditions could change in the future
- From the data, probability of compliance (ammonia, *E. coli*, chlorine residual) has been > 99%
- Potential financial penalties of non-compliance are small ($10,000 per day)
- What level of risk is acceptable? The answer varies from utility to utility

Risk Associated with Current Disinfection Approach (from Existing Data)

Option	Ammonia Permit Compliance Risk	E. Coli Permit Compliance Risk	Dechlorination Permit Compliance Risk	Complexity of Operation
Current Approach (NTF Bypass)	0.7%* (1 in 140 Days)	0.9%** (1 in 107 Days)	0.07%*** (1 Day in 4 Years)	High

Notes:

Risk quantification based on existing data, using more stringent criteria than permit language, thus actual risk of permit violation was less than the values shown

Data set analyzed: from 1/1/09 through 4/17/11

* 6 in 837 daily samples had ammonia concentration $\geq$ 4.0 mg-N/L

** 7 of 750 daily grab samples had *E. coli* levels $\geq$ 252 per 100 mL

*** 14 of 20120 hourly readings had ORP $\geq$ 240 mV

Risk Comparison of Disinfection Options

Option	Ammonia Permit Compliance Risk	E. Coli Permit Compliance Risk	Dechlorination Permit Compliance Risk	Safety Issues	Complexity of Operation
Current Approach (NTF Bypass)	0.7% (1 in 140 Days)	0.9% (1 in 107 Days)	0.07% (1 Day in 4 Years)	Medium	High
Modified Current Approach (NTF Bypass with Improvements)	Slightly Lower Risk (Reduced Compared to Current Approach)	Slightly Lower Risk (Reduced Compared to Current Approach)	No Change	No Change	No Change
Preformed Monochloramine	Lower Risk (Reduced Compared to Current Approach)	Lower Risk (Reduced Compared to Current Approach)	No Change	Higher (Additional Chemical Required)	Lower
UV	Lowest Risk (Reduced Compared to Other Options)	Lower Risk (Reduced Compared to Current Approach)	No Risk (Do Not Need to Dechlorinate)	Lower	Lower

Disinfection Option Cost Comparison

TABLE 2 – ESTIMATED COSTS

Option	Capital Cost	Annual Operating Costs
Current Approach with Modifications	$1,200,000	$118,000 / year
Preformed Monochloramine[1]	$2,100,000	$120,000 / year
UV[2]	$7,125,000	$88,000 / year

1. Capital costs represent a Class 4 estimate and include piloting, design, SDCs, and construction of new building for aqueous ammonia storage and feed. Operating costs include costs for 2 mg/L of sodium hypochlorite and 0.5 mg/L aqueous ammonia at an average flow of 23 mgd.
2. Costs for UV were identified in B&C's January 26, 2011 memorandum entitled "Evaluation of Alternative Disinfection Methods to Comply with the Recent Proposed Ammonia Limits". Annual Operating Costs were further refined in March of 2011 by B&C using Ozonia equipment information.

Summary

- Decision should be based on risk, cost, and values
- Current process has consistently met the 2014 ammonia and E. Coli standards
- Risk vs. Cost:
  - UV is the option with lowest risk and highest cost
  - Existing approach with modifications has higher risk, but lower cost
- Values are specific to your community

Littleton/Englewood WWTP Assessment of Existing Disinfection System

Special Meeting
June 28, 2011

CH2MHILL

1697 Cole Boulevard, Suite 200
Golden, Colorado 80401
Tel: 303-239-5400
Fax: 303-239-5454
www.brownandcaldwell.com

July 15, 2011

Brown AND Caldwell

Gary Sears
Englewood City Manager
1000 Englewood Parkway
Englewood, CO 80110

Project Number: 140714

Subject: Comments on CH2MHill's Presentation and Slides of the L/E WWTP Disinfection System

Dear Mr. Sears:

As requested, Brown and Caldwell (BC) was present during CH2MHill's presentation to the Joint Councils on June 28th, 2011, and has reviewed their presentation slides on the Assessment of the Existing Disinfection System. In summary, BC did not perform or review the quantitative risk assessment that was presented; however, we generally agree with CH2MHill's findings. The UV disinfection system was recommended based on a greater inherent risk associated with the current disinfection system and L/E's corresponding management objectives. BC remains confident in its recommendation for UV disinfection at the L/E WWTP, other benefits in addition to alleviating the risks of the current system. CH2MHill touched on a few of these, along with the L/E Ammonia Compliance study which BC completed.

These include:

- Decreasing health/safety risks, as there is no need for the transport, storage, or handling of toxic chemicals hazardous to workers and the community
- Eliminating existing chlorine and dechlorination processes, which in turn removes the associated chlorine residual limit from L/E's permit
- Allowing the plant to operate at full potential to remove as much ammonia as possible from L/E's effluent, thus improving water quality

Other benefits of disinfecting with UV include:

- Effective bacterial disinfection
- Effective cyst disinfection
- No residual toxicity
- No disinfection by-products
- No chemicals added to the water
- Noncorrosive
- No associated odors
- No associated change in effluent pH
- No associated change in effluent color
- Minimal operator safety risks

- Easy to operate and control
- Simple and easy to maintain
- Components and operating supplies are readily available
- No associated Homeland Security issues
- No residual removal requirements
- Low operating costs
- Consistent with all L/E WWTP Management Objectives
- Consistent with all existing and anticipated effluent requirements, including anticipated emerging contaminant and nutrient removal requirements

As stated above, we generally agree with CH2MHill's findings. Upon review of the slides and the presentation, there were a few items which merit additional commentary:

Slide 11 – Of note – The plant "almost exceeded future E. coli limits in the summer of 2010."

Slide 15 – CH2MHill stated that UV would ultimately be required with potential new disinfection requirements. Also of note, CDPHE's recently-proposed nutrient requirements, when enforced, will require the L/E WWTP to implement UV disinfection.

Slide 16 – Noted difficulties with UV Disinfection – Comment - Potential difficulties with UV disinfection are minor. The UV pre-design considers back-up power alternatives to ensure UV disinfection disruptions are minimal.

Slide 18 – Noted Assessment of Risk -: "probabilities of compliance (ammonia, E. coli, Chlorine residual) are 99%."

BC did not perform a quantitative risk assessment, but we do not disagree with the comments. However, the quantified risk of 99% is subjectively interpreted as "very low". The 1% probability of non-compliance may result in up to 15 to 20 possible permit violations – assumption is 1500 to 2000 annual samples multiplied by 1%.

The intent of CH2MHill's study is to re-evaluate the feasibility of chlorine disinfection options. The re-evaluation criteria do not reference the L/E management objectives, which are the criteria under which the plant operates and with which treatment designs are to comply. However, CH2MHill's final assessment yielded results similar to those in BC's Ammonia Compliance Study. BC's recommendation is to continue with the installation of UV disinfection at the L/E WWTP.

Very truly yours,

Brown and Caldwell

Kirk Petrik, Project Manager
Denver

Mary Gearhart, Division Manager
Denver

KGP:ll